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INSTALLATION RESTORATION PROGRAM (IRP)

**SITE S-5
REMEDIAL INVESTIGATION**

VOLUME I

**KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS**

**HALLIBURTON NUS ENVIRONMENTAL CORPORATION
FOSTER PLAZA 7
661 ANDERSEN DRIVE
PITTSBURGH, PENNSYLVANIA 15220**

JULY 1992

FINAL

PREPARED FOR

**UNITED STATES AIR FORCE
AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
ENVIRONMENTAL RESTORATION DIVISION
TECHNICAL OPERATIONS BRANCH (ESO/ERT)
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INSTALLATION RESTORATION PROGRAM (IRP)

**SITE S-5
REMEDIAL INVESTIGATION**

VOLUME I

**FINAL
FOR**

**KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS**

JULY 1992

PREPARED BY

**HALLIBURTON NUS ENVIRONMENTAL CORPORATION
FOSTER PLAZA 7
661 ANDERSEN DRIVE
PITTSBURGH, PENNSYLVANIA 15220**

USAF CONTRACT NO. F33615-90-D-4011, DELIVERY ORDER NO. 0004

**ENVIRONMENTAL MANAGEMENT
TECHNICAL PROJECT MANAGER
DEANNA PIERRE**

**AIR FORCE LOGISTICS COMMAND
ENVIRONMENTAL MANAGEMENT
KELLY AIR FORCE BASE, TEXAS 78241**

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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) HALLIBURTON NUS Environmental Corporation Foster Plaza VII 661 Andresen Drive Pittsburgh, PA 15220				8. PERFORMING ORGANIZATION REPORT NUMBER R-49-9-91-6	
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13. ABSTRACT (Maximum 200 words) Site S-5 is located behind Building 1618 along the eastern side of the Kelly AFB Flightline. An aqua-fuels system, which is believed to be the major source of contamination at Site S-5, is located in the vicinity of Building 1617. Petroleum products stored in the Building 1617 fuel farm included aviation gasoline (Avgas), jet fuel, control unit calibrating fluid, and waste oils. Potentially, any of these fluids could have been released from the tanks and associated piping systems during the operation of the facility. Currently, all eight tanks are empty and located to prevent any further use. A site characterization study and remedial investigation was conducted in two phases at Site S-5 to assess the type and extent of soil and groundwater contamination at the site. Several volatile organics, dissolved lead, and petroleum hydrocarbons were detected in groundwater samples. Analytical results for Phase 2 were generally lower than those for Phase 1.					
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EXECUTIVE SUMMARY

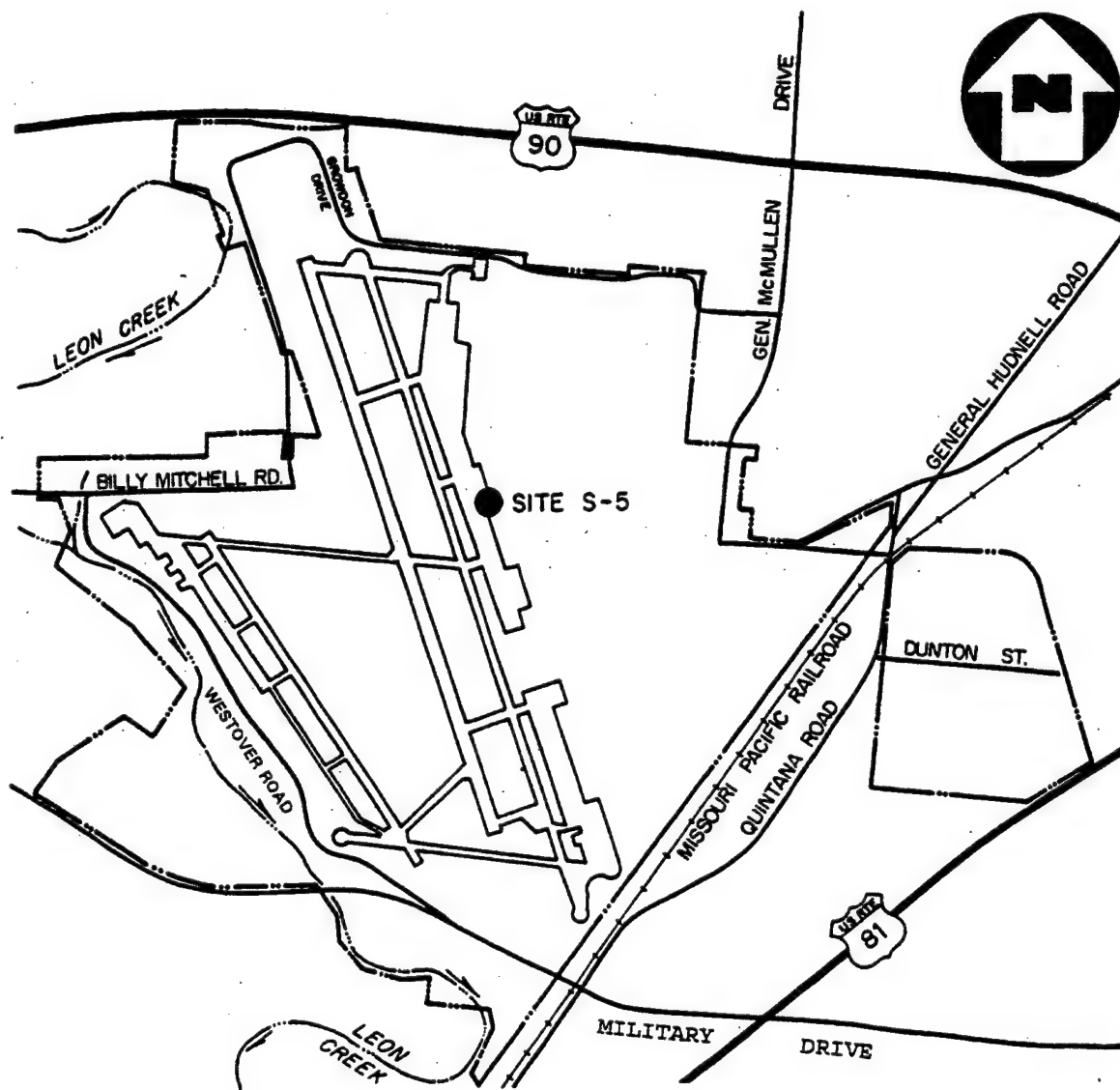
This Remedial Investigation Report for Site S-5 at Kelly Air Force Base determines that remedial action is necessary. A feasibility study is currently being conducted to define and evaluate alternative remedial responses for the site.

This RIR is intended to characterize the nature and extent of contamination in soils and groundwater, and to provide an assessment of the risk presented by this contamination and its potential migration within the shallow groundwater aquifer.

The U.S. Air Force Installation Restoration Program identifies, evaluates and remediates environmental contamination. Kelly AFB Site S-5 has been contaminated by past storage and handling of aviation gasoline (avgas), jet fuel, and liquid hazardous wastes. See Figure ES-1 for the Site S-5 Location Map. Site S-5 is located behind Building 1618 along the eastern side of the Kelly AFB flightline. Eight 25,000-gallon underground storage tanks at Site S-5 were used to store leaded aviation gas from 1926 until about 1950, when the system was converted to dispense jet fuel. Three above-ground 10,000-gallon storage tanks and two 10,000-gallon underground storage tanks are also at the site. See Figure ES-2 for the site plan. Beginning in 1970, the tanks were used to store control unit calibrating fluids and waste oil. The tanks and their associated underground piping are now empty. Figure ES-2 provides the locations of various buildings and tanks in the S-5 Site area.

The investigation of Site S-5 was carried out in two phases. The first (1990) involved 31 temporary monitoring wells and 8 soils borings. Phase II (1991) used 18 of the phase I wells, 11 new monitoring wells and 2 well borings for soil samples. Field and fixed-base laboratory analysis of samples collected during the remedial investigation indicated the following:

- Several volatile organics, dissolved lead, and petroleum hydrocarbons were detected in groundwater samples. Groundwater contamination is limited to the surficial aquifer and groundwater flow is generally to the south-southeast.
- There appear to be three primary sources of groundwater contamination. The S-5 tank farm is the major source, particularly for contaminants associated with fuels (toluene, benzene, dissolved lead and petroleum hydrocarbons). Chlorinated solvents, such as tetrachloroethene (PCE), trichloroethene (TCE), and trans-1,2-dichloroethene (DCE), appear related to sources south of Building 1600 and to the northwest along the flightline.



LEGEND

— KELLY AFB BOUNDARY

0 3000 6000
SCALE IN FEET

FIGURE ES-1

SITE S-5 LOCATION MAP
KELLY AFB, SAN ANTONIO, TX



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Environmental Corporation

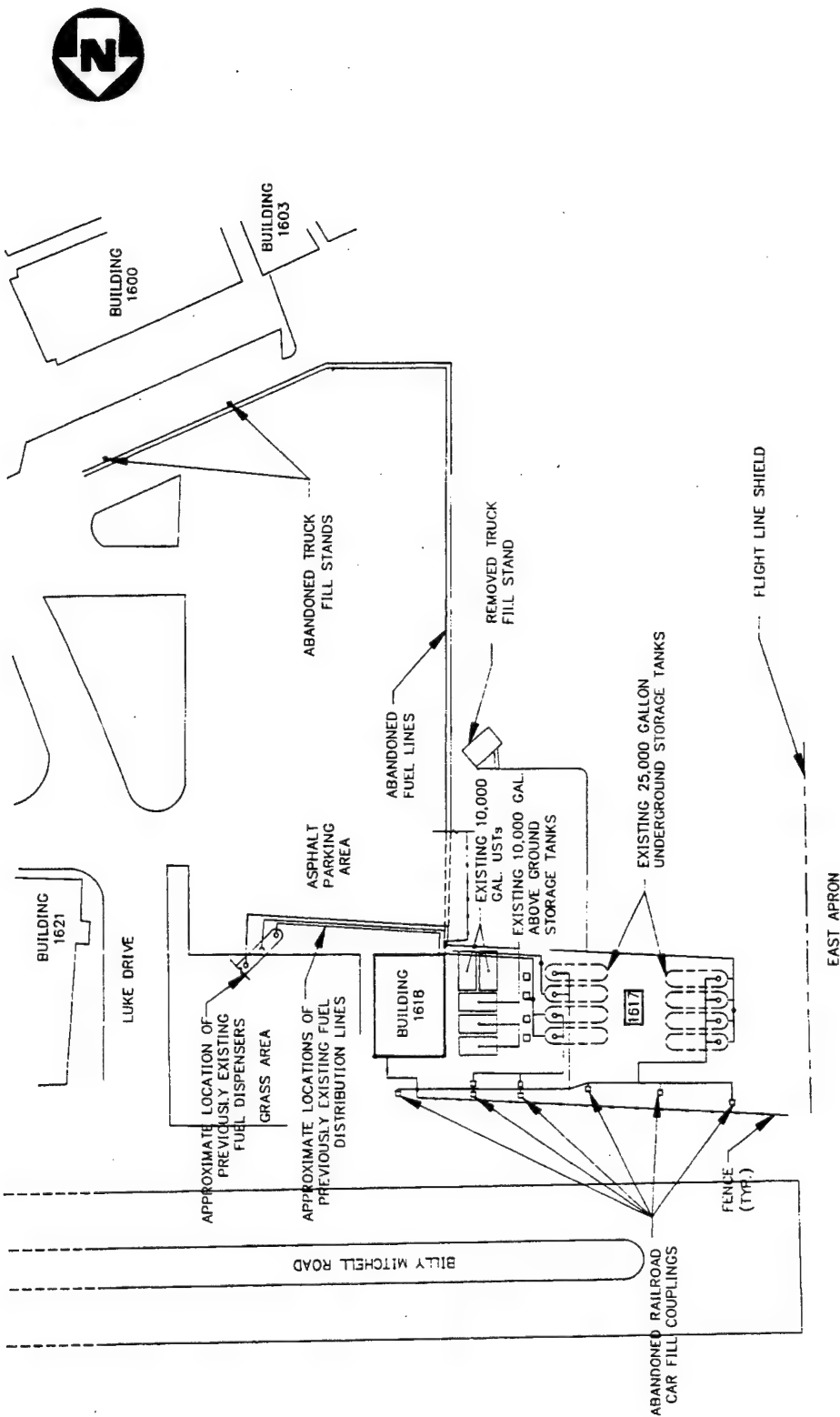
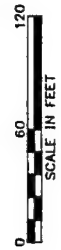


FIGURE ES-2



SITE PLAN
KELLY AFB S-5

- Subsurface soils outside the tank farm exhibit low levels of contamination. Phase two field testing and phase field and fixed-base laboratory analysis verified the presence of volatile organics and petroleum hydrocarbons in the soils.

All potential exposure to soil contaminants at Site S-5 present carcinogenic risks that fall within the acceptable range as established by the U.S. Environmental Protection Agency (1×10^{-4} x 10^{-6} incremental cancer risk). One future scenario, potential domestic use of groundwater, presents a Hazard Index greater than unity which reflects an unacceptable health risk to residents and employees if a well were constructed to use the shallow aquifer beneath Site S-5 as a source of potable water.

1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Air Force, due to its primary mission in defense of the United States, has long been engaged in a wide variety of operations dealing with toxic and hazardous materials. This problem has been recognized by the Department of Defense (DOD), and action has been taken to identify the locations and contents of past disposal sites and to minimize the hazards to public health in an environmentally responsible manner.

In 1975, the DOD developed the Installation Restoration Program (IRP) to identify, report, and correct potential environmental problems from past waste disposal and spill sites on Air Force installations and develop remedial actions consistent with the National Contingency Plan (NCP) for those sites which pose a threat to human health and welfare or the environment. This objective is achieved through a Remedial Investigation/Feasibility Study (RI/FS) process in which conclusions and recommendations drawn from accurate data are used to structure and guide subsequent activities. Initial guidance for the four-phased IRP was published in January 1982. The IRP Guidance Manual was revised in 1989 and reflects the influence of the Superfund Amendments and Reauthorization Act (SARA) of 1986.

The RI/FS process includes scoping to define data requirements and objectives, a remedial investigation to characterize sites for a baseline risk assessment, and a feasibility study to define and evaluate alternative remedial actions so that a recommended action may be selected. Each of these steps in the RI/FS process can be conducted in stages that focus on particular aspects of the process.

1.2 AUTHORITY

This preliminary draft Remedial Investigation (RI) report for Site S-5 at Kelly Air Force Base (AFB) has been prepared by HALLIBURTON NUS Environmental Corporation under contract F33615-90-D-4011, Delivery Order No. 0004, with the Air Force Systems Command, Human Systems Division (HSD). This RI meets the requirements set forth in the HSD Statement of Work, dated January 7, 1991.

1.3 SITE BACKGROUND

1.3.1 Site Description

Kelly AFB is located in Bexar County, approximately seven miles from the center of San Antonio. The Base is bounded on the west by Lackland AFB and to the south by Military Drive and Leon Creek. The eastern and northern boundaries of Kelly AFB are the Missouri-Pacific Railroad yards and Highway 90, respectively. The base area consists of 3,929 acres.

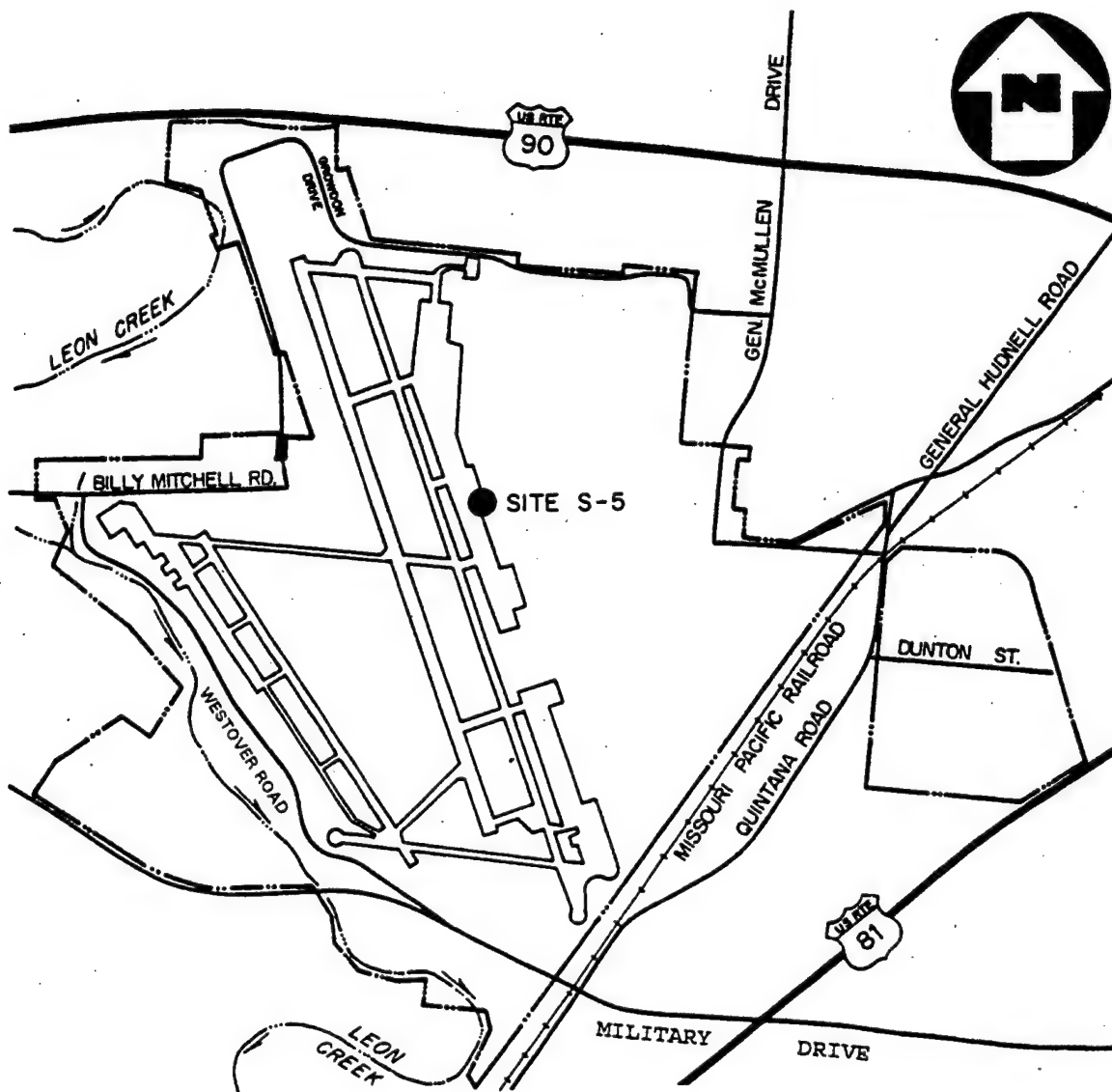
Kelly AFB was founded in 1917 as the first military air base in Texas. For the past 34 years, Kelly AFB has been involved in logistics and maintenance. Kelly's primary mission is to support the San Antonio Air Logistics Center (SA-ALC) of the Air Force Logistics Command. The SA-ALC is the systems support manager for the Military Airlift Command's C-5 Galaxy jet transport fleet. In addition, SA-ALC is responsible for depot maintenance for the Strategic Air Command's B-52 bomber fleet. The SA-ALC also manages more than one-half of the entire Air Force engine inventory. Kelly AFB also acts as host to approximately 56 tenant organizations that represent the Air Force, the Army, the Department of Defense, and various other government agencies.

1.3.2 Site History

Site S-5 is located west of Building 1618 along the eastern side of the Kelly AFB Flightline (see Figure 1-1). The aqua-fuel system, which is the major source of contamination at Site S-5, is located in the vicinity of Building 1618.

Petroleum products stored in the Building 1618 fuel farm (Figure 1-2) include aviation gasoline (Avgas) that contains lead, jet fuel, control unit calibrating fluid, and waste oils. Potentially, any of these fluids could have been released from the tanks and associated piping systems during the operation of the facility.

The Building 1618 aqua-fuels system was constructed around 1926. The original system included eight 25,000-gallon steel underground storage tanks (USTs). The system dispensed aviation gasoline and included two distribution lines. One distribution line ran 100 feet south from the tanks and then 70 feet east to a truck fill stand. The second line ran a total of 690 feet to a truck fill stand just north of the armament depot (present day Building 1600). Building 1600 is approximately 500 feet south of the Building 1618 tank farm as shown on Figure 2-1. By 1944, the original truck fill stand southeast of the tanks had been removed and an extension was added to the 690-foot line. It is unknown if these lines ever leaked or if they were removed with the fill stands.



LEGEND

— KELLY AFB BOUNDARY

0 3000 6000
SCALE IN FEET

FIGURE 1-1

**SITE S-5 LOCATION MAP
KELLY AFB, SAN ANTONIO, TX**



HALLIBURTON NUS
Environmental Corporation

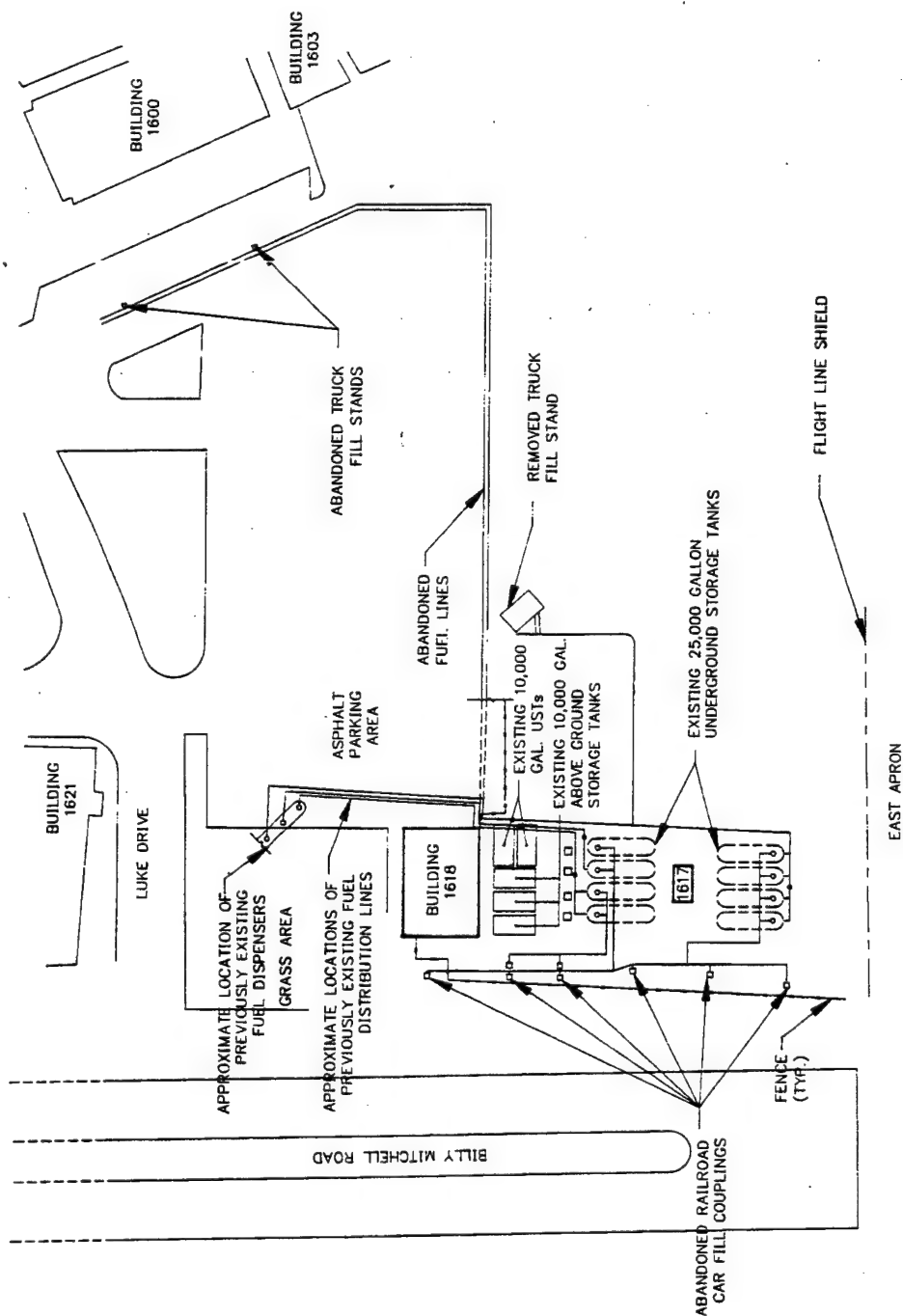


FIGURE 1-2



SITE PLAN
KELLY AFB S-5

All fuels were delivered by rail car to the aqua-fuel system. Fill lines from the railroad tracks north of the tank farm were used to directly fill the tanks.

In 1937, Building 1618 was constructed for oil storage and distribution. Three 10,000 gallon above ground storage tanks were installed. These three oil tanks were filled by rail cars and the oil was dispensed along the south side of Building 1618. No underground distribution lines were used to dispense oil. In addition, two 10,000 gallon steel USTs were installed just west of Building 1618. It is not known whether these tanks were tar coated and their operation history is unknown. The two USTs were taken out of service in 1978. Figure 1-2 depicts all tank locations in the Building 1618 tank farm area.

The aqua-fuel system was converted to jet fuel about 1950. Fuel continued to be dispensed through the above described system, supplying trucks for refueling aircraft on the flightline. During this period of operation, Avgas storage was phased out of the USTs and into the three 10,000 gallon above-ground tanks behind Building 1618. The truck fill stands continued to dispense both types of fuel until the system was closed.

In 1969-1970 the Building 1592 above-ground storage and hydrant distribution system began operation. This new system, located on the north side of the base, replaced the Building 1618 aqua-fuel system.

Used petroleum products were stored in the USTs at Building 1618 from 1970 to the present. Tanks 1 through 4 were operated by the Directorate of Maintenance (SA-ALC/MAQV) for less than 90-day storage of used calibrating fluid before its resale as a waste fuel oil. Tanks 5 through 8 were managed by Civil Engineering and Industrial Waste Treatment Plant (IWTP) personnel for storage of other petroleum wastes such as product recovered from a spill or skimmings from the IWTP. Tanks 5 through 8 were only used on an as-needed basis and disposal was arranged on a case-by-case basis. No distribution systems were used during this operation. All tanks were filled and pumped out directly.

In-house tank tightness testing was done in the summer of 1989. Results indicated no detectable releases from the tanks at that time. Additionally, all tanks were tar coated when installed. Therefore, the storage tanks themselves may not be the major source of underground contamination. Underground piping systems, manways, vent pipes, and other connections to the USTs may be the primary sources of leaks. Spills may also have occurred due to overfilling and product handling at the

USTs, and therefore, the soils immediately surrounding the tanks and areas where fuel was dispensed may be a second source of contamination.

Since no piping systems were used during the storage of used petroleum products (1970 to present), the potential for release of these wastes is lower than for fuel products.

Currently, all tanks are empty and locked to prevent further use. Future plans for the site include removal of the USTs. A base fire station is planned for the area just northwest of Building 1618. Parking lot or traffic control areas may overlap a portion of the site area.

1.3.3 Previous Investigations

1.3.3.1 Preliminary Field Work

Preliminary field work completed in September 1989 (Chen Northern, Inc.) detected both soil and groundwater contamination at Site S-5. Eight soil borings were drilled and three were converted to monitoring wells. Both soil and groundwater samples were analyzed for total petroleum hydrocarbons (TPH), purgeable aromatics (EPA 8020), volatile organic halocarbons (EPA 8010), and heavy metals.

Four of the soil borings were completed within the limits of the tank farm. These borings were installed to define contaminant levels in the backfill and soil contiguous to the tanks. Soil samples were taken at 5-foot intervals. All samples were analyzed for TPH, aromatics, and metals. One sample per boring was also analyzed for VOHs. Findings indicated that the soils within the tank farm were contaminated with petroleum hydrocarbons and lead. Volatile organics (aromatics) such as benzene, ethylbenzene, toluene, and xylene, all of which would be expected at a fuel spill site, were also present.

Lead, which was detected in the soil from the surface to the water table in concentrations ranging from 2.17 mg/kg to 35.8 mg/kg, possibly originated from leaks of Avgas. Low levels of volatile organic halocarbons, which were present in some of the waste petroleum products stored at the site, were also detected in the soil. 1,1,1-trichloroethane and 1,1,2-trichloroethane were both detected at concentrations of approximately 1 mg/kg. Carbon tetrachloride was noted as being present in trace amounts but the concentration was not quantifiable.

All three monitoring wells contained a free-phase floating product, ranging in thickness from 0.87 to 1.28 feet. Although elevated levels of TPH were reported in the water phase in each well, no chlorinated solvents were detected.

Lead was detected in the groundwater at concentrations of 7.0 mg/L and 7.59 mg/L. It is not known whether groundwater samples were filtered before analysis. As indicated above, the presence of lead is probably the result of releases of Avgas.

1.3.3.2 Site Investigation Field Work (Phase 1 - October 1990)

Phase 1 field work performed by HALLIBURTON NUS under Delivery Order No. 0001, was completed in October 1990. The investigation confirmed the presence of both soil and groundwater contamination at Site S-5. A total of eight (8) soil borings and thirty one (31) monitoring wells were drilled. Both soil and groundwater samples were analyzed for total petroleum hydrocarbons (TPH), target volatile organics and semivolatile organics, and lead.

The analysis of target volatile organic compounds in the field laboratory indicated that toluene, ethylbenzene, benzene, and 1,2,4-dichlorobenzene were present in the soil. It should be noted that the highest positive detections were in soils at the approximate elevation of the water table, indicating probable soil contamination by floating product. The confirmatory analysis of volatile compounds by the fixed base laboratory, however, revealed positive results for acetone only, at relatively low concentrations. Soil samples contained lead at concentrations ranging from 5 mg/kg to 28 mg/kg. In general, the results for lead did not reveal any trends that would indicate the presence of source areas at the boring locations. Petroleum hydrocarbons were detected in only two borings, both at a depth of 24.5 feet (approximate elevation of the water table).

Several samples were also analyzed in the field laboratory for target semivolatile organics. No semivolatiles were detected in any of the samples.

Groundwater samples were analyzed initially by the field laboratory, with second column confirmations performed at the fixed-base laboratory. These results revealed positive results for benzene, toluene, tetrachloroethene (PCE), trichloroethene (TCE), trans-1,2-dichloroethene (DCE), petroleum hydrocarbons, and dissolved lead. The pattern of groundwater contamination appears to indicate two distinct sources, the Site S-5 tank farm at Building 1618, and an unknown source in the vicinity south of Building 1600. No target semivolatile organic compounds were detected in any of the groundwater samples.

Light free phase liquid (floating product) was detected in one of the three original existing wells in the immediate vicinity of Building 1618 during Phase 1.

1.3.3.3 Remedial Investigation Field Work (Phase 2 - July 1991)

Phase 2 field work performed by HALLIBURTON NUS under Delivery Order No. 0004 was completed in June 1991. Results from Phase 2 are presented in detail in this report and are used in conjunction with the Phase 1 data to define the extent of contamination and to estimate potential public health risks.

1.4 REPORT ORGANIZATION

This report is organized into seven sections. Section 1, Introduction, discusses the project background and site background. The site background section includes the site description, site history, and a summary of previous investigations. In addition, this section discusses the structure of the report.

Section 2, Field Investigation, discusses the Phase 1 and 2 field activities associated with site characterization. These activities include geological and hydrogeological investigations and related environmental sampling.

Section 3, Physical Characteristics of the Site, includes the results of field activities to determine such physical characteristics as regional and local geology, and groundwater hydrology.

Section 4, Nature and Extent of Contamination, presents the results of site characterization for the chemical components and contaminants of the soils and groundwater. This section details the quantitative and qualitative nature of contaminants found at the site as well as their areal extent.

Section 5, Contaminant Fate and Transport, discusses the chemical and physical properties of site chemicals, the potential routes of migration, and contaminant persistence.

Section 6, Baseline Risk Assessment, discusses the human health risks as a function of exposure assessment and toxicity. An evaluation of related environmental risks is also presented.

Section 7, Summary and Conclusions, presents a summary of the topics discussed in sections 4, 5, and 6. Also discussed are data limitations and recommendations for future work.

2.0 FIELD INVESTIGATION

2.1 PROJECT OBJECTIVES

A site characterization was conducted in two phases at Site S-5 to assess the type and extent of soil and groundwater contamination at the site. Specific objectives of the project were as follows:

- Define the approximate limits of dissolved and floating product plumes.
- Define the type and approximate vertical distribution of soil contamination.
- Determine groundwater flow direction.
- Provide data to support the design of an interim recovery system.

To accomplish these objectives, 31 temporary monitoring wells were installed and sampled during the SI phase (Phase 1). Three existing monitoring wells were also sampled at that time. Eighteen of the temporary monitoring wells were completed as temporary wells while the remaining 13 wells were removed at the completion of the Phase 1 activities. Two of the wells were found to be dry and were not sampled. In addition, eight soil borings were drilled and soil samples collected and analyzed.

Once the first set of wells was completed, it was determined that additional data was needed to better define the limits of the plumes. During the subsequent RI phase (Phase 2), 11 additional borings were drilled, two of which included soil sampling, and all were converted to temporary monitoring wells. Upon completion of the 11 temporary wells, a total of 29 temporary wells were present at the site. Of these 29 wells, 15 were converted to permanent wells and the remaining 14 were pulled and grouted.

2.2 FIELD ACTIVITIES

The field investigation activities, as developed in the Final Field Sampling Plan (NUS, October 1990), are briefly summarized in the following sections. Table 2-1 summarizes all field activities that were conducted in October 1990 and June/July 1991. All drilling was performed by Fugro Geosciences, Inc., under subcontract to HALLIBURTON NUS Environmental Corporation and directed in the field by HALLIBURTON NUS representatives.

TABLE 2-1

**FIELD INVESTIGATION SUMMARY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS**

Component	Purpose	Description
Soil Borings	To obtain subsurface soil samples for chemical and physical analysis (site characterization)	1990 - Eight on-site soil borings. 1991 - Two on-site soil borings.
Subsurface Soil Sampling	Soil contaminant characterization.	1990 - 41 samples of the on-site subsurface soil for chemical analysis. 1991 - 15 samples of the on-site subsurface soil for chemical analysis.
Monitoring Wells	Floating product and dissolved contaminant identification.	1990 - Drilling, installation, and development of 31 overburden wells. 1991 - Drilling, installation, and development of 11 overburden wells.
Groundwater Sampling	Groundwater contamination characterization.	1990 - One round of sampling for chemical analysis from 29 new wells and 3 existing monitoring wells. Two wells were dry. 1991 - One round of sampling for chemical analysis from 11 new wells and 21 existing wells.
Surveying	Locate all sampling sites.	Survey all sampling locations.

2.2.1 Borehole Drilling

Eight soil borings were drilled as part of the Phase 1 field investigation to characterize subsurface soil contamination at selected locations. Hollow stem augers were used to advance the soil borings. Soil samples were collected at 5-foot intervals, to the top of the Navarro Group. The samplers had an inside diameter of 2.5 inches and were two feet long to fulfill sample volume requirements for chemical analysis. No drilling fluids were used during soil boring activities. After the borings were drilled to the desired depth, they were grouted to the ground surface with a cement-bentonite slurry (approximately 94 percent cement and 6 percent bentonite by weight). The slurry was emplaced using a tremie pipe.

A complete log of each soil boring (See Appendix A) was maintained in accordance with the Field Sampling Plan (HALLIBURTON NUS, October 1990).

Soil boring locations are shown on Figure 2-1. Soil boring data are summarized on Table 2-2. Soil borings SB-06, SB-54, and SB-55 were converted to monitoring wells (TW-06, TW-54, and TW-55) upon completion of the soil sampling.

2.2.2 Temporary Monitoring Well Construction/Installation

Thirty-one temporary monitoring wells were drilled and installed in 1990 to help define the floating product plume and characterize groundwater contamination. Eleven additional temporary monitoring wells were installed in 1991. As with the soil borings, the hollow stem auger drilling technique was used to advance the well borings. The temporary monitoring wells were constructed of 2-inch I.D. PVC flush-joint riser pipe and flush-joint factory slotted well screen (0.02-inch slot size).

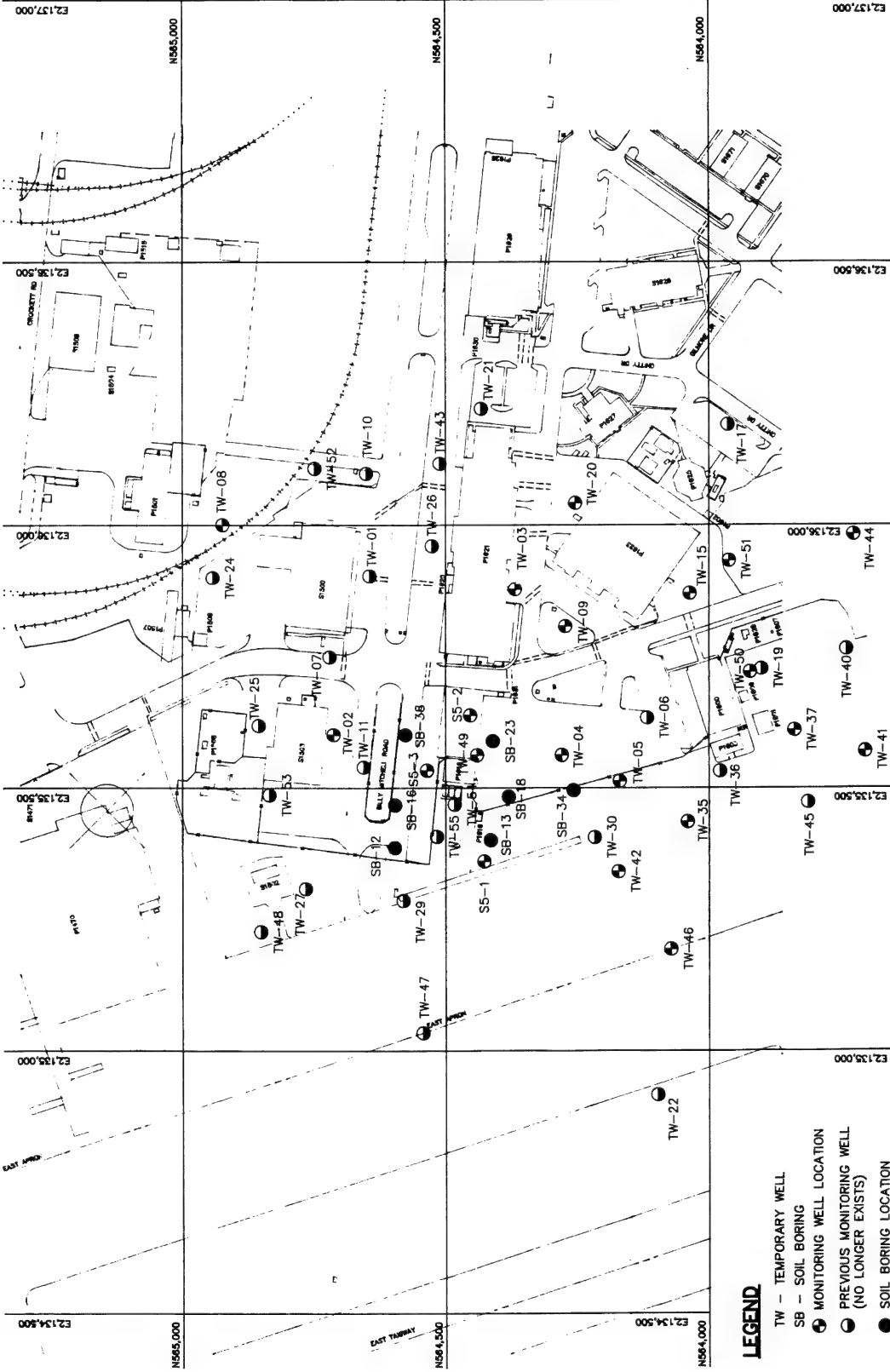
The top of the screened intervals were positioned approximately one to two feet above the stabilized water level. Screen lengths ranged from 5 to 15 feet. After the borings were drilled to the desired depth (6-inch minimum diameter boring), the wells were installed through the augers. A silica sand pack was installed in the boring annulus around the well screen as the augers were withdrawn from the boring. The sand packs extend approximately two feet above the top of the well screens. Bentonite pellet seals approximately two feet thick were installed above the sand packs. The remainder of the boring annulus was temporarily allowed to remain open. The well tops were secured with expandable rubber, packer-type caps and locked with keyed-alike locks.

After the 31 Phase 1 wells were completed, sampled, and surveyed, 13 were pulled from the borings and the borings were grouted to the ground surface with a cement-bentonite slurry. Those that

TABLE 2-2
SOIL BORING SUMMARY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Boring Number	Ground Elevation	Total Depth (Ft)	Depth to Navarro
*TW-06	681.98	26.0	26.0
SB-12	683.80	28.0	26.0
SB-13	683.99	32.0	31.5
SB-16	683.63	30.5	30.5
SB-18	683.17	29.5	29.0
SB-23	683.88	32.0	32.0
SB-34	682.10	31.0	30.0
SB-38	683.85	28.5	28.5
*TW-54(1)	684.85	34.0	34.0
*TW-55(1)	684.77	33.0	32.0

- * Soil boring converted to temporary well.
(1) Temporary monitoring wells installed during Phase 2.



MONITORING WELL/SOIL BORING LOCATIONS
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

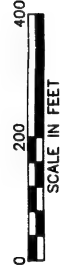


FIGURE 2-1

remained (18) were provided with flush-mount type protective casings. Seven of the ten Phase 2 wells were pulled and grouted, and four were converted to permanent wells with flush-mount casings.

Monitoring well construction data are summarized on Table 2-3. A monitoring well construction diagram was completed for each temporary well installed (See Appendix B). Boring logs for the monitoring wells are also presented in Appendix A.

2.2.3 Well Development

The temporary monitoring wells were developed after installation to remove fine material from the area around the monitored interval of the well. Wells were developed by bailing and surging, or by pumping, depending on the field conditions. Wells were developed by removing from three to eight well volumes or until approved by the field geologist. Development water was collected, containerized, and discharged into the Kelly AFB IWTP.

2.2.4. Water Level Measurement

At least one complete round of water level measurements was obtained from all monitoring wells upon completion of both phases of the investigation. All measurements were taken within a 24-hour period of consistent weather conditions to minimize atmospheric/precipitation effects on groundwater levels. Measurements were taken with an M-scope (electrical water-level indicator), using the top of the well casing as the reference point for determining depths to water. Water-level measurements were recorded to the nearest 0.01 foot in the field logbook.

To confirm the absence or presence of a floating petroleum hydrocarbon layer in the monitoring wells, measurements (in wells within close proximity to the tank farm) were collected with the use of an oil-water interface probe and also with a clear bailer.

To obtain measurements using the oil-water interface probe the following steps were taken:

- Lower the probe down the well until it comes in contact with the floating petroleum layer (probe emits steady noise).
- Record the depth to the top of the floating layer.

TABLE 2-3

**MONITORING WELL SUMMARY
SITES 5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS**

Well Number	Well Status		Ground Elevation(1)	Top of Casing Elevation(1)	Total Depth (Feet)(2)	Screened Interval (Feet)(2)	Floating Product (Yes/No)	Depth to Navarro Group (Feet)(2)
	Left as Temporary Well	Removed After Sampling						
TW-01	X		683.04	682.88	32.4	17.2-32.2	NO	30.5
TW-02	X		684.64	684.31	31.7	16.5-31.5	NO	31.0
TW-03	X		682.29	682.09	29.0	17.8-27.8	NO	28.0
TW-04	X		682.89	682.72	32.0	16.8-31.8	NO	31.0
TW-05	X		681.43	681.44	32.2	17.0-32.0	NO	30.5
TW-06	X		681.98	681.83	26.0	14.5-24.5	NO	26.0
TW-07	X		683.53	683.38	33.0	17.0-32.0	NO	32.0
TW-08	X		683.12	682.75	29.2	18.0-28.0	NO	28.0
TW-09	X		682.54	682.27	32.5	17.3-32.3	NO	30.5
TW-10		X	683.03	682.78	32.0	16.8-31.8	NO	31.5
TW-11		X	684.00	683.91	31.8	16.6-31.6	NO	30.5
TW-15	X		680.69	680.57	30.0	18.5-28.5	NO	29.0
TW-17		X	680.25	679.97	28.4	18.2-28.2	NO	27.5
TW-19		X	679.30	679.06	23.0	17.2-22.2	NO	22.0
TW-20	X		681.34	681.13	28.7	18.5-28.5	NO	28.0
TW-21	X		682.07	682.10	31.2	16.0-31.0	NO	30.5

TABLE 2-3
MONITORING WELL SUMMARY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Well Number	Well Status		Ground Elevation ⁽¹⁾	Top of Casing Elevation ⁽¹⁾	Total Depth (Feet) ⁽²⁾	Screened Interval (Feet) ⁽²⁾	Floating Product (Yes/No)	Depth to Navarro Group (Feet) ⁽²⁾
	Left as Temporary Well	Removed After Sampling						
TW-22		X	680.54	681.49	22.0	16.8-21.8	NO	21.0
TW-24		X	684.67	684.43	28.0	17.8-27.8	NO	27.5
TW-25		X	684.98	684.84	29.1	18.9-28.9	NO	28.0
TW-26		X	684.09	683.92	31.3	16.1-31.1	NO	30.5
TW-27		X	684.83	685.84	24.6	14.4-24.4	NO	23.5
TW-29		X	684.74	687.86	28.5	17.1-27.1	NO	27.5
TW-30		X	682.72	682.55	29.0	18.0-28.0	NO	28.0
TW-35	X		680.92	680.63	27.5	17.0-27.0	NO	26.0
TW-36		X	680.64	680.46	23.5	17.5-22.5	NO	22.0
TW-37	X		678.31	678.20	22.7	17.5-22.5	NO	22.0
TW-40		X	678.20	677.45	21.5	15.8-20.8	NO	21.5
TW-41	X		678.50	678.15	22.0	16.5-21.5	NO	22.0
TW-42	X		682.58	682.42	29.5	18.0-28.0	NO	29.0
TW-43	X		683.77	683.61	31.5	16.1-31.1	NO	31.0
TW-44		X	679.35	678.93	26.7	16.1-26.1	NO	26.0

TABLE 2-3
MONITORING WELL SUMMARY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE THREE

Well Number	Well Status		Ground Elevation ⁽¹⁾	Top of Casing Elevation ⁽¹⁾	Total Depth (Feet) ⁽²⁾	Screened Interval (Feet) ⁽²⁾	Floating Product (Yes/No)	Depth to Navarro Group (Feet) ⁽²⁾
	Left as Temporary Well	Removed After Sampling						
*TW-45		X	679.18	679.03	22.0	10.0-20.0	NO	22.0
*TW-46	X		681.60	681.13	34.0	22.5-32.5	NO	32.0
*TW-47		X	684.43	684.23	29.0	17.0-27.0	NO	27.0
*TW-48		X	685.85	685.94	32.5	22.0-32.0	NO	32.5
*TW-49	X		683.80	683.73	33.0	22.0-32.0	NO	31.0
*TW-50	X		679.76	679.61	27.0	15.2-25.2	NO	25.0
*TW-51	X		680.75	680.57	23.0	13.0-23.0	NO	23.0
*TW-52		X	682.84	682.71	31.5	21.0-31.0	NO	31.0
*TW-53		X	684.64	684.24	28.0	18.0-28.0	NO	27.5
*TW-54		X	684.85	684.95	34.0	20.0-30.0	NO	34.0
*TW-55		X	684.77	684.39	33.0	20.0-30.0	NO	32.0
**S5-1	NA	NA	NA	686.95	NA	NA	YES ⁽³⁾	NA
**S5-2	NA	NA	NA	686.29	NA	NA	NO	NA
**S5-3	NA	NA	NA	686.51	NA	NA	YES [0.34']	NA

NA Not applicable. Wells installed prior to 1990.

(1) Feet above mean sea level.

(2) Feet below ground surface.

(3) The presence of an oil skimmer prevented direct measurement. Floating product has been reported in this well by Kelly AFB personnel.

* Temporary wells installed during Phase 2 (1991).

** Permanent wells installed during the preliminary investigation (1989).

- Lower the probe further until it comes in contact with water (when contact is made with water, probe emits beeping sound).
- Record the depth to the top of water table.
- The difference between the two readings will indicate the apparent thickness of the petroleum hydrocarbon layer.

When obtaining measurements with the clear bailer, the bailer was lowered down the well until it reached the petroleum layer. The bailer was allowed to further descend the total length of the bailer only, then removed. This method allowed the geologist to visually observe the apparent thickness of the petroleum layer.

2.2.5 Hydraulic Conductivity

In-situ hydraulic conductivity testing (rising-head slug tests) were performed on 28 wells during Phase 2 field activities. Slug tests were performed to provide approximate hydraulic conductivity values for the portion of the formation immediately surrounding the screened interval of the well.

The slug tests consisted of instantaneously changing the water level within the wells and measuring the rate of recovery of the water level to equilibrium conditions. The water level change was performed by rapidly removing a solid cylinder of known volume (slug), then measuring the recovery (rising head) over time.

Rate of recovery measurements were obtained using a pressure transducer and a computerized data logger. Recovery data was obtained from time zero (maximum change in water level) until water level recovery exceeded 90 percent of the initial change in water level.

The following information was collected for each well during the performance of the aquifer tests:

- Well number/depth/screened interval/inside diameter of screen/diameter of sand pack.
- Static water level.
- Time/recovery data.
- Total time of test.

2.2.6 Sampling Procedures

2.2.6.1 Subsurface Soil Sampling

Subsurface soil samples were collected from ten soil borings drilled at the site. The samples were collected in accordance with the Field Sampling Plan (HALLIBURTON NUS, October 1990). Soil samples were collected at 5-foot intervals to the top of the Navarro Group. Upon sample retrieval, the sampler was opened and sufficient volume was obtained for volatile organics analysis. The remaining material was homogenized and distributed to the remaining sample containers. Samplers were decontaminated between samples as described in Section 2.2.5.2.

2.2.6.2 Groundwater Sampling

Groundwater samples were obtained from each of the temporary groundwater monitoring wells. Groundwater sampling was conducted in accordance with the Field Sampling Plan (HALLIBURTON NUS, October 1990).

Prior to obtaining samples, water levels were measured and the wells were purged using a dedicated bailer or a suction pump. Three to eight well volumes were purged. If the wells were purged dry with less than three well volumes removed, the water level in the well was allowed to recover at least 70 percent, then a sample was collected. In the event that recovery was slow, samples were collected within 24 hours of purging. Field measurements of pH, temperature, specific conductance, and turbidity were taken at the beginning, middle, and end of purging according to Field Sampling Plan (HALLIBURTON NUS, October 1990).

Dedicated bailers were used for sample collection. The samples were poured directly from the bailer into the appropriate sample bottles for analysis.

2.2.6.3 Waste Sampling

All drill cuttings were containerized in four hazardous waste dumpsters. Cuttings were consolidated and composite samples were collected and analyzed for determination of the appropriate disposal method. Development water and purge water were containerized and discharged into the Kelly AFB IWTP without sampling.

2.2.6.4 Sample Handling

Sample handling includes the field-related considerations connected with the selection of sample containers, preservatives, allowable holding times and analyses requested. The User's Guide to the Contract Laboratory Program (U.S. EPA, December 1986), and the Code of Federal Regulations (U.S. EPA, September 1990) address the topics of containers and sample preservation. Table 2-4 provides a summary of sample handling considerations.

Samples were packaged and shipped in accordance with the Field Sampling Plan (HALLIBURTON NUS, October 1990). The Field Operations Leader was responsible for completion of the following forms:

- Sample labels
- Chain-of-custody forms
- Appropriate labels applied to shipping coolers
- Chain-of-custody labels
- Federal Express airbills

2.2.6.5 Sample Custody

Custody of samples was maintained and documented at all times. Chain-of-custody began with the collection of the samples in the field. The Field Sampling Plan (HALLIBURTON NUS, October 1990) provides a description of the chain-of-custody procedures that were followed.

2.2.7 Surveying

All temporary monitoring wells and soil borings were surveyed following installation. Existing survey monuments at Kelly AFB were used as reference points. Horizontal locations were surveyed to Kelly AFB coordinates, which are tied to the Texas State Plane Coordinate System. Monitoring well and soil boring horizontal locations were surveyed to the nearest 0.1 foot.

Vertical elevations were referenced to the 1929 National Geodetic Vertical Datum. For each temporary monitoring well, the elevation of the top of the uncapped riser was determined to the nearest 0.01 foot. For both monitoring well and soil boring locations, ground surface elevations were surveyed to the nearest 0.1 foot.

TABLE 2-4

SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS, AND HOLDING TIMES

SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Media	Analysis	Number of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Groundwater	Total petroleum hydrocarbons (fixed base lab)	1	1 liter glass bottle	H ₂ SO ₄ to pH <2; Cool to 4°C	28 days
	Lead (total recoverable) (fixed base lab)	1	1 liter polyethylene bottle	HNO ₃ to pH <2; Cool to 4°C	6 months
	Volatile organics (field lab)	4	40 mL VOA vials	Cool to 4°C	7 days to analysis
	Semivolatiles organics (field lab)	4	40 mL VOA vials	Cool to 4°C	7 days to extraction; 40 days to analysis
	Volatile organics (fixed base lab)	2	40 mL VOA vials	HCl to pH <2; Cool to 4°C	14 days to analysis
	Semivolatiles organics (fixed base lab)	1	1 gallon amber glass bottle	HCl to pH <2; Cool to 4°C	14 days to analysis
	Pesticides/PCBs (fixed base lab)	1	1/2 gallon amber glass bottle	Cool to 4°C	7 days to extraction; 40 days to analysis
	pH, temperature, specific conductivity, turbidity	N/A	N/A	N/A	Analyze immediately
	Total petroleum hydrocarbons (fixed base lab)	1	8 oz. amber wide mouth glass jar	Cool to 4°C	28 days
	Lead (total recoverable) (fixed base lab)	1	8 oz. amber wide mouth glass jar	Cool to 4°C	6 months
Subsurface Soil	Volatile organics (field lab)	1	4 oz. clear wide mouth jar w/teflon cap	Cool to 4°C	7 days to analysis
	Volatile organics (fixed base lab)	3	4 oz. clear wide mouth jar w/teflon cap	Cool to 4°C	7 days to analysis

TABLE 2-4
SUMMARY OF ANALYSIS, BOTTLE REQUIREMENTS, PRESERVATION REQUIREMENTS, AND HOLDING TIMES
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Media	Analysis	Number of Containers Per Sample	Container Type	Preservation Requirements	Holding Times
Subsurface Soil (Continued)	Semivolatile organics (field lab)	1	4 oz. clear wide mouth jar w/teflon cap	Cool to 4°C	7 days to extraction; 40 days to analysis
	Semivolatile organics (fixed base lab)	1	4 oz. clear wide mouth glass jar w/teflon cap	Cool to 4°C	7 days to extraction; 40 days to analysis
	Pesticides/PCBs (fixed base lab)	1	4 oz. clear wide mouth glass jar w/teflon cap	Cool to 4°C	7 days to extraction; 40 days to analysis
Cuttings	Toxicity characteristic leaching procedure (TCLP)	1	32 oz. wide mouth glass jar	None	7 days to extraction; 28 days to analysis
	BTEX	1	8 oz. amber wide mouth glass jar w/teflon cap	Cool to 4°C	7 days to analysis
	Lead (total recoverable)	1	8 oz. amber wide mouth glass jar	Cool to 4°C	6 months
	Total petroleum hydrocarbons	1	8 oz. amber wide mouth glass jar	Cool to 4°C	28 days
	Total organic halogens	1	8 oz. amber wide mouth glass jar w/teflon cap	Cool to 4°C	7 days to analysis

2.2.8 Decontamination

All equipment involved in field sampling activities was decontaminated prior to and during drilling and sampling activities. This equipment included drilling rigs, downhole tools, augers, well casing and screens, and soil and water sampling equipment.

2.2.8.1 Major Equipment

All downhole drilling equipment, including downhole drilling and sampling tools, was steam-cleaned prior to beginning work, between boreholes, and at the conclusion of the drilling program. Well casing and screens were steam-cleaned prior to being installed into the borings. All decontamination activities took place at the Kelly AFB IWTP.

2.2.8.2 Sampling Equipment

All sampling equipment used for collecting samples was decontaminated both prior to beginning field sampling and between samples. The following decontamination steps were taken:

- Potable water rinse
- Alconox or liquinox detergent wash
- Potable water rinse
- Reagent Grade II water rinse
- Pesticide-grade methanol rinse
- Pesticide-grade hexane rinse
- Air dry

Field analytical equipment such as pH, conductivity, and temperature instrument probes were rinsed first with Reagent Grade II water then with the sample liquid.

2.2.9 Waste Handling

All development and purge liquids were collected and discharged into the Kelly AFB Industrial Waste Treatment Plant (IWTP) via the influent sewer system. Discharge to the IWTP was at a rate such that IWTP operations were not adversely affected.

All drill cuttings were bulked in four hazardous waste dumpsters. Composite samples were collected from the dumpsters and analyzed to determine if the material was a hazardous waste or if it could be disposed of in a permitted sanitary landfill.

2.2.10 Recordkeeping

In addition to chain-of-custody records associated with sample handling, packaging, and shipping, certain standard forms were completed for sample description and documentation. These included Sample Log Sheets (for subsurface soil and groundwater samples), Daily Record Subsurface Investigation Reports, and Logbooks.

A bound/weatherproof field notebook was maintained by the sampling event leader. The field team leader, or designee, recorded all information related to sampling or field activities. This information included sampling time, weather conditions, unusual events (e.g., breakdown), field measurements, description of photographs, etc.

A site logbook was maintained by the Field Operations Leader. The requirements of the site logbook are outlined in the Field Sampling Plan (HALLIBURTON NUS, October 1990). This book contains a summary of the day's activities and references the field notebook when applicable.

The field team leader who was supervising the drilling subcontractor activity completed a Daily Record Subsurface Investigation Report. The Daily Record Subsurface Investigation Report documented the activities and progress of the daily drilling activities. The information contained within this report will be for billing verification and progress reports. The driller's signature appears at the end of each working day to verify work accomplished, hours worked, standby time, and material used.

At the completion of field activities, the FOL submitted to the Project Manager all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheets, drilling logs, daily logs, etc.

2.3 ANALYTICAL PROGRAM

A summary of the analytical program for Site S-5 is presented in Table 2-5. Samples were analyzed in the field laboratory at Kelly AFB as well as in the HALLIBURTON NUS Laboratory in Pittsburgh, Pennsylvania. The field laboratory and fixed base laboratory programs are described in the following sections.

TABLE 2-5

SUMMARY OF SAMPLING AND ANALYSES PROGRAM

SITE S-5

KELLY AIR FORCE BASE

SAN ANTONIO, TEXAS

Matrix	Analysis	Target Detection Limit	Analytical Method	Source of Analysis	Number of Samples	Field Duplicates	Equipment Blanks	Ambient Conditions Blanks	Trip Blanks	Total Analyses
Groundwater (1990)	Conductivity	NA	NA	Field Analysis	29	0	0	0	0	29
	pH	NA	NA	Field Analysis	29	0	0	0	0	29
	Temperature	NA	NA	Field Analysis	29	0	0	0	0	29
	Turbidity	NA	NA	Field Analysis	(1)	0	0	0	0	(1)
	Target Volatile Organics	(2)	Mod. EPA 624	Field Lab	32(3)	3	3	4	12	54
	Target Semivolatile Organics	(2)	Mod. SW3510/8270	Field Lab	6	0	1	1	0	8
	Total Petroleum Hydrocarbons	1 mg/L	EPA 418.1	Fixed Base Lab	31	4	4	0	0	39
	Lead	0.005 mg/L	SW 3005/7421	Fixed Base Lab	32	3	4	0	0	39
	Conductivity	NA	NA	Field Analysis	32	0	0	0	0	32
	pH	NA	NA	Field Analysis	32	0	0	0	0	32
Groundwater (1991)	Temperature	NA	NA	Field Analysis	32	0	0	0	0	32
	Turbidity	NA	NA	Field Analysis	32	0	0	0	0	32
	Target Volatile Organics	(2)	Mod. EPA 624	Field Lab	10	1	1	1	0	13
	Volatile Organics	(4)	SW8240	Fixed Base Lab	32	3	3	0	5	43
	Semivolatile Organics	(4)	SW8270	Fixed Base Lab	7	1	1	0	0	9
	Pesticides/PCBs	(4)	SW8080	Fixed Base Lab	2	1	1	0	0	4
	Total Petroleum Hydrocarbons	1 mg/L	EPA 418.1	Fixed Base Lab	11	1	0	0	0	12
	Target Volatile Organics	(2)	Mod. EPA 624	Field Lab	41	7	0	0	0	48
	Target Semivolatile Organics	(2)	Mod. SW3550/8270	Field Lab	20	3	0	1	0	24
	Volatile Organics	(4)	SW8240	Fixed Base Lab	6	4	0	0	4	14
Subsurface Soil (1990)	Total Petroleum Hydrocarbons	30 mg/kg	SW3550/EPA 418.1	Fixed Base Lab	40	7	0	0	0	47
	Lead	1 mg/kg	SW3550/6010	Fixed Base Lab	40	7	0	0	0	47
	Target Volatile Organics	(2)	Mod. EPA 624	Field Lab	9	1	1	0	0	11
	Volatile Organics	(4)	SW8240	Fixed Base Lab	6	1	0	0	0	7
	Semivolatile Organics	(4)	SW3550/8270	Fixed Base Lab	2	1	0	0	0	3
	Pesticides/PCBs	(4)	SW3550/8080	Fixed Base Lab	2	1	0	0	0	3
	Lead	1 mg/kg	SW3550/6010	Fixed Base Lab	4	1	0	0	0	5
	Total Petroleum Hydrocarbons	25 mg/kg	SW3550/EPA 418.1	Fixed Base Lab	4	1	0	0	0	5
	Conductivity	NA	NA	Field Analysis	32	0	0	0	0	32
	pH	NA	NA	Field Analysis	32	0	0	0	0	32

TABLE 2-5
SUMMARY OF SAMPLING AND ANALYSES PROGRAM
SITE 5-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Matrix	Analysis	Target Detection Limit	Analytical Method	Source of Analysis	Number of Samples	Field Duplicates	Equipment Blanks	Ambient Conditions Blanks	Trip Blanks	Total Analyses
Cuttings (1990)	TCLP Extraction/Analysis	(4)	App. 2, 40CFR261	Fixed Base Lab	3	0	0	0	0	3
Cuttings (1991)	Total Petroleum Hydrocarbons	30 mg/kg	SW3550/EPA 418.1	Fixed Base Lab	2	0	0	0	0	2
	TCLP Extraction/Analysis	(4)	App. 2, 40CFR261	Fixed Base Lab	1	0	0	0	0	1
	Lead (total recoverable)	1 mg/kg	SW3550/6010	Fixed Base Lab	1	0	0	0	0	1
	Benzene/Toluene/Ethylbenzene/ Xylenes	1 µg/kg each	SW8020	Fixed Base Lab	1	0	0	0	0	1
	Total Organic Halogens	1 mg/kg	SW9020	Fixed Base Lab	1	0	0	0	0	1

(1) Turbidity meter did not function because of high turbidity of groundwater. Qualitative descriptions were recorded.

(2) As per Kelly AFB Field Laboratory QAPP.

(3) 30 samples had 2nd column confirmation at fixed base laboratory.

(4) Chemical-specific, as required by method.

2.3.1 Field Laboratory Analytical Program

The field analyses for samples collected at Site S-5 were conducted at HALLIBURTON NUS' field laboratory at Kelly AFB. For samples requiring volatile organic analysis, the following target compounds were analyzed:

- Benzene
- Toluene
- Ethylbenzene
- Chlorobenzene
- 1,2-Dichlorobenzene
- 1,3/1,4-Dichlorobenzene
- Tetrachloroethene
- Trichloroethene
- trans-1,2-Dichloroethene
- 1,1-Dichloroethane

Volatile organics analyses for both soil and water were performed using a modification of EPA Method 624. This was also the methodology used for other concurrent work being performed at Kelly AFB (Zones 1, 2, and 3 under the HAZWRAP contract).

For samples requiring semivolatile organics analysis, the following target compounds were analyzed:

- Phenol
- 2-Methylphenol
- 3-Methylphenol
- 4-Methylphenol
- 2,6-Dimethylphenol
- 2,4-Dimethylphenol
- 2,4,6-Trichlorophenol
- Di-n-butyl phthalate
- Bis(2-ethylhexyl) phthalate
- Butyl benzyl phthalate
- Di-n-octyl phthalate
- Naphthalene
- Fluoranthene

Semivolatile organics analyses were conducted using modified SW846 Methods 3550/3510 and 8270. Again, to ensure comparability of all field laboratory data collected at Kelly AFB, the analytical methods used for Site S-5 were the same as were used for the HAZWRAP contract sites.

2.3.2 Fixed-Base Laboratory Analytical Program

The fixed base laboratory analyses were performed at the HALLIBURTON NUS Laboratory in Pittsburgh, Pennsylvania. The analyses performed were lead and total petroleum hydrocarbons for both soil and groundwater samples, volatile organics for some soils and groundwater, and second column gas chromatograph confirmation analysis of target volatile organics in groundwater samples.

Analysis of drill cuttings was performed in both 1990 and 1991. In 1990, one composite sample from the three dumpsters was collected and subjected to TCLP extraction and analysis. In 1991, one composite sample was collected from a fourth dumpster for TPH analysis, one composite sample was collected from the three 1990 dumpsters for TPH analysis, and one composite sample was collected from all four dumpsters for the following analyses (as required by the Texas Department of Health):

- Total organic halogens (TOX)
- TCLP extraction/Zero head space extraction and analysis
- Total lead
- Benzene, Toluene, Ethylbenzene, and Total Xylenes (BTEX)

2.3.3 Quality Control (QC) Samples

In addition to periodic calibration of field equipment and appropriate documentation, quality control samples were collected or generated during environmental sampling activities. Quality control samples included field duplicates, field blanks, and trip blanks. Each type of field quality control sample is defined as follows:

Field (Equipment Rinsate) Blanks - Field blanks were obtained under representative field conditions by running analyte-free deionized water through sample collection equipment (bailer, split spoon, corer, etc.) after decontamination and placing it in the appropriate sample containers for analysis. Field blanks were used to assess the effectiveness of decontamination procedures. Field blanks were collected for each type of nondedicated sampling equipment used and were submitted at a frequency of one per every ten samples or one per sampling trip if less than ten samples were collected.

Field Duplicates - Field duplicates are samples that are divided into two portions at the time of sampling. Field duplication provides precision information regarding homogeneity, handling, shipping, storing, preparation, and analysis. Field duplicates were submitted at a frequency of one per every ten samples, or one per sampling trip if less than ten samples were collected.

Trip Blanks - Trip blanks are collected when analyzing for volatile organics, and were prepared on a one per day frequency. Trip blanks were sent from the fixed-base laboratory along with the sample bottles, and kept under refrigeration until used. Trip blanks were obtained at the beginning of each day and were subjected to the same field conditions as field samples. Trip blanks were used to check for cross contamination of volatiles in the sample coolers during sampling and shipping.

Ambient Condition Blanks - Ambient condition blanks are Type II Reagent Grade Water that is poured into sample containers at a sampling site. They were handled like a sample and transported to the laboratory for analysis.

The field quality control samples are included in Table 2-5. The use of these samples in determining quality of the laboratory data is described in the Informal Technical Information Report (HALLIBURTON NUS, September 1991).

2.3.4 Field Measurements and Equipment Calibration

Field measurements that were recorded during groundwater sampling activities included temperature, pH, specific conductance, and turbidity. Instruments used in the field to record this data were calibrated according to the procedures described below.

Several monitoring instruments were used during field activities, including

- Temperature probe
- Specific conductance meter
- pH meter
- Electronic water-level meter
- Turbidity meter

The electronic water-level meter was calibrated prior to mobilization and periodically at the discretion of the FOL. The remaining instruments were calibrated according to the manufacturer operating manuals.

Calibration was documented on an Equipment Calibration Log. During calibration, an appropriate maintenance check was performed on each piece of equipment.

3.0 PHYSICAL CHARACTERISTICS OF THE SITE

3.1 GEOLOGIC SETTING

3.1.1 Regional Geology

The San Antonio area lies within two distinct physiographic provinces, the Edwards Plateau on the northwest, and the West Gulf Coastal Plain on the southeast. These provinces are separated by the Balcones Escarpment, which is an east-west trending fault that serves as the recharge zone for the Edwards Aquifer. Kelly Air Force Base is located within the West Gulf Coastal Plain approximately 15 miles southeast of the escarpment.

The West Gulf Coastal Plain consists of a thick sequence of unconsolidated sediments overlying predominantly calcareous sedimentary bedrock. The beds dip between 15 to 150 feet per mile to the southeast toward the coast. The Coastal Plain sediments were deposited in both marine and near shore alluvial environments and vary in age from Cretaceous to Recent.

3.1.2 General Site Geology

Due to the shallow depth of the alluvial aquifer at the site, the field drilling program was confined to the top 30 feet of the subsurface. Boring log data from 42 monitoring wells and 10 soil borings were used to interpret site geologic conditions. Figure 3-1 shows the location of the monitoring wells, soil borings, and three cross-sections that were developed from data collected during the two-phase site investigation. Cross-sections A-A' through C-C' are shown in Figures 3-2, 3-3, and 3-4, respectively.

The shallow subsurface geology of the study area consists of a thin veneer of fill material overlying approximately 1 to 20 feet of alluvial silty clays that contain thin, discontinuous sand and gravel lenses. Caliche (calcium carbonate cement) was encountered in most of the borings as nodules or thin coatings on gravels. In addition, occasional cobbles were noted at varying depths. Below the silty clay is a 5- to 10-foot layer of clayey gravel. This alluvial gravel bed is saturated and is the water-bearing unit for the surficial aquifer. Beneath these gravels is the Navarro Group, which is a stiff, silty clay that forms the aquitard for the shallow water aquifer. The Navarro was identified below the deepest gravelly clay layer in each boring, at which point the boring was halted.

Soil density varies from stiff to very stiff depending on the amount of gravel present. Because these near surface soils were deposited in a regressive alluvial environment, the lithology is varied and discontinuous within a relatively short distance. The basal gravels thus were deposited on an eroded surface of the Navarro Group. A contour map of the top of the Navarro Group, based on boring logs, is shown in Figure 3-5.

3.2 HYDROLOGIC SETTING

3.2.1 Regional Hydrogeology

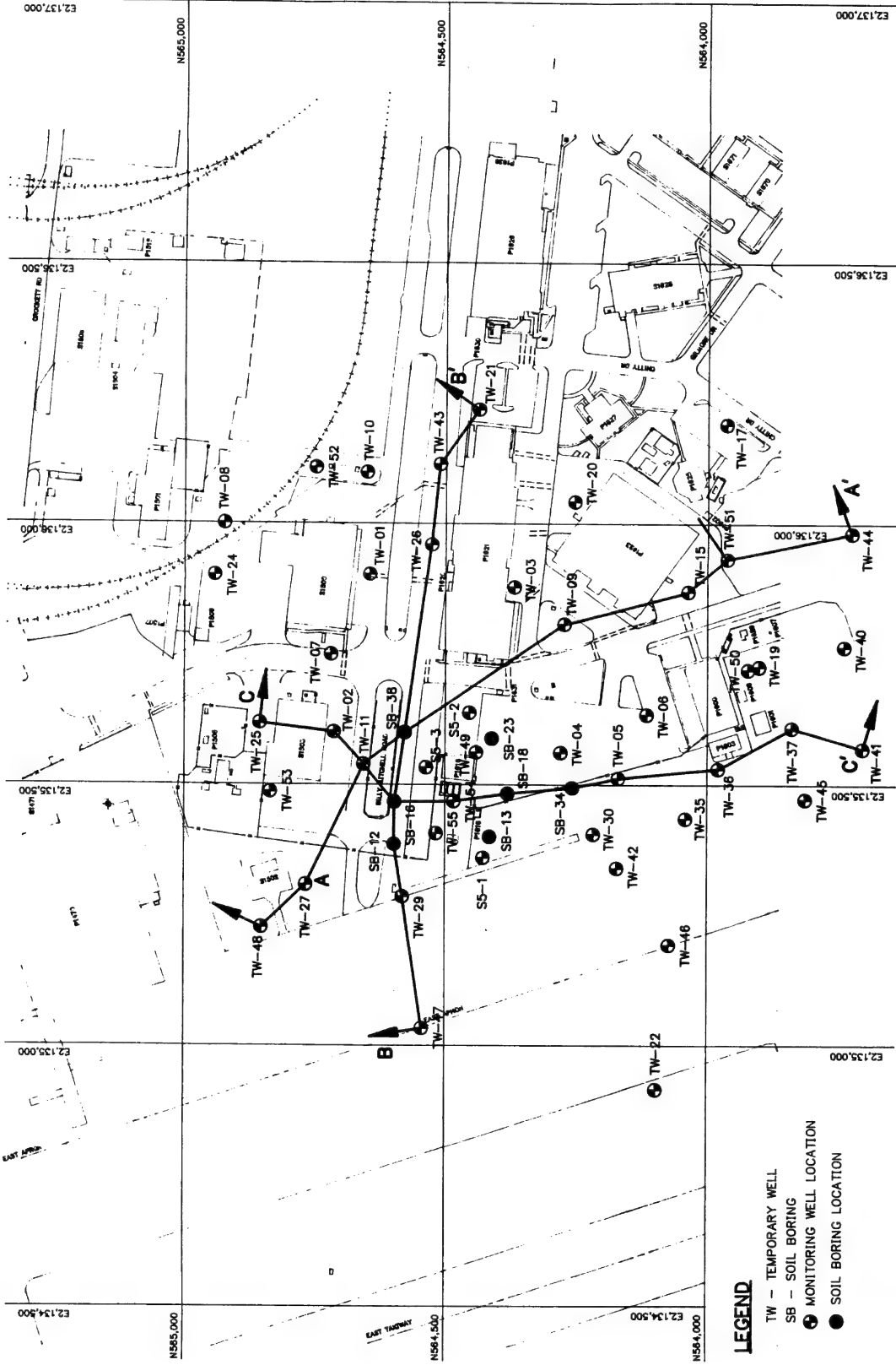
The West Gulf Coastal Plain consists of a sequence of aquifers made up of interbedded sands and permeable limestones separated by confining units of less permeable clays and calcareous clays. The shallow alluvial aquifer is the principal aquifer of concern in this report.

The alluvial aquifer is composed of medium to coarse, poorly sorted gravels in a silty clay matrix. This deposit ranges in thickness from five to ten feet and is not used as a drinking water supply in the study area. The Navarro Group forms the lower boundary of the shallow alluvial aquifer and separates it from the deeper Edwards Aquifer. The Navarro Group is several hundred feet thick and is thus an important regional aquitard. The hydraulic conductivity from samples of the Navarro Group tested previously yielded low vertical hydraulic conductivity values ranging from 9.1×10^{-10} cm/sec to 1.3×10^{-8} cm/sec (HALLIBURTON NUS, January 1990).

3.2.2 General Site Hydrogeology

The alluvial aquifer at Site S-5 is located in the near surface clayey gravel at depths of approximately 20 to 30 feet in the vicinity of the tank farm. Two wells drilled during Phase 1 (TW-40 and TW-22) produced no water and several others (TW-19, -24, -25, -27, -36, and -41) produced very little water in comparison to the majority of the wells. These wells were located on the northern and southern flanks of the site as well as across the flightline apron area on the west side of the site. These dry zones are areas where the elevation of the Navarro Group surface is higher than the elevation of the groundwater (potentiometric surface). In addition, because the gravel bed pinches out in localized areas, the normal migration of groundwaters can be restricted.

The hydraulic gradient is difficult to predict due to discontinuity of the gravels and the eroded surface of the Navarro Group. Table 3-1 presents the three rounds of water level elevations taken in the wells during Phase 2 of the field investigation (1991). The potentiometric surface contours, shown on Figure 3-6, are based on one round of water level data obtained in 1990 from the monitoring wells



MONITORING WELL, SOIL BORING, AND CROSS SECTION LOCATION MAP
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

A'

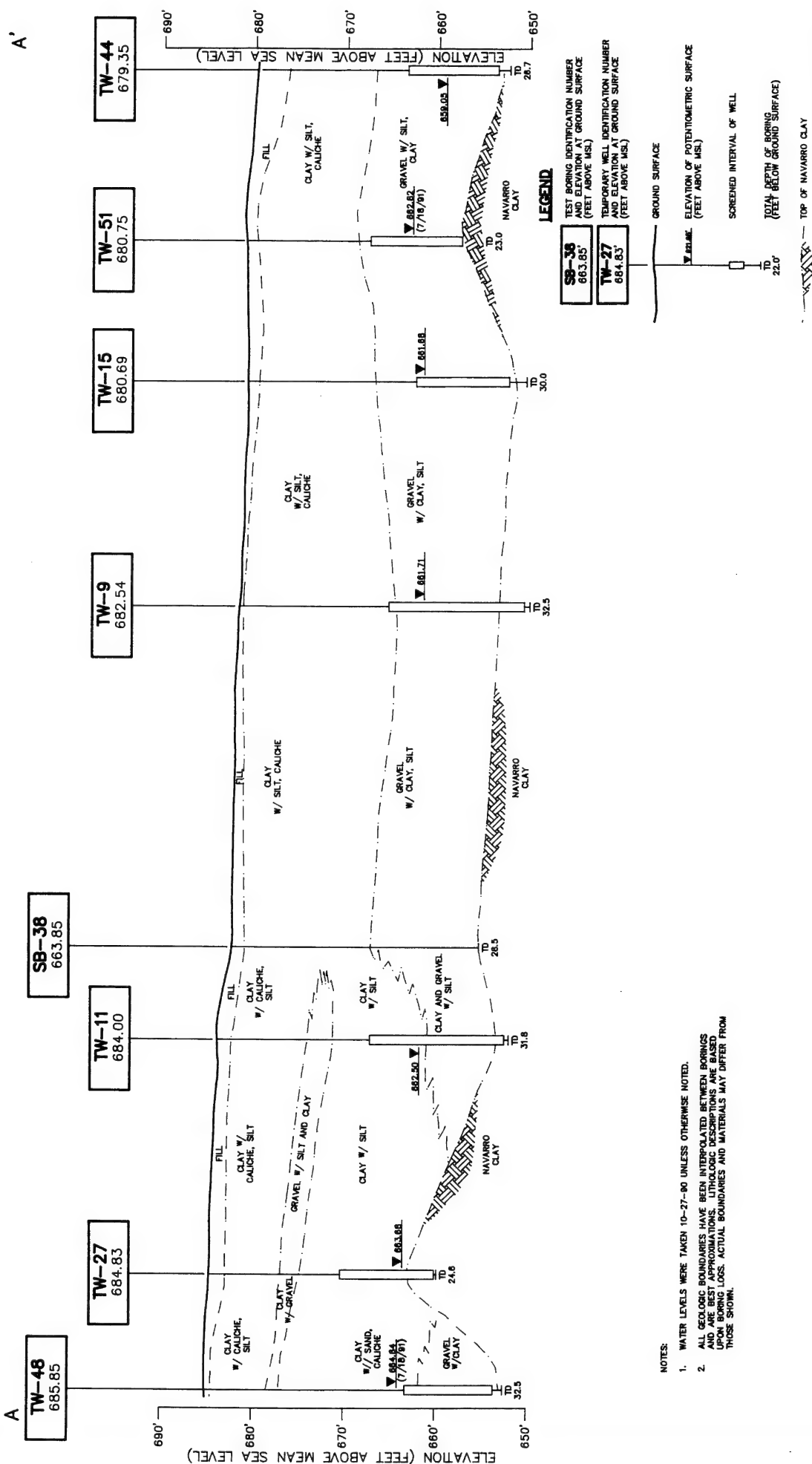
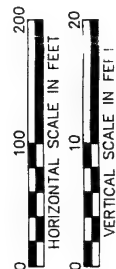


FIGURE 3-2



CROSS SECTION A-A'
SITE S-5
KELLY AFB, SAN ANTONIO, TX



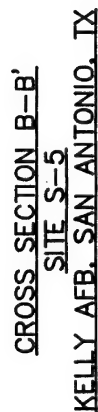
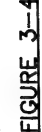


FIGURE 3-3



HALLIBURTON NUS
Environmental Corporation

3-7



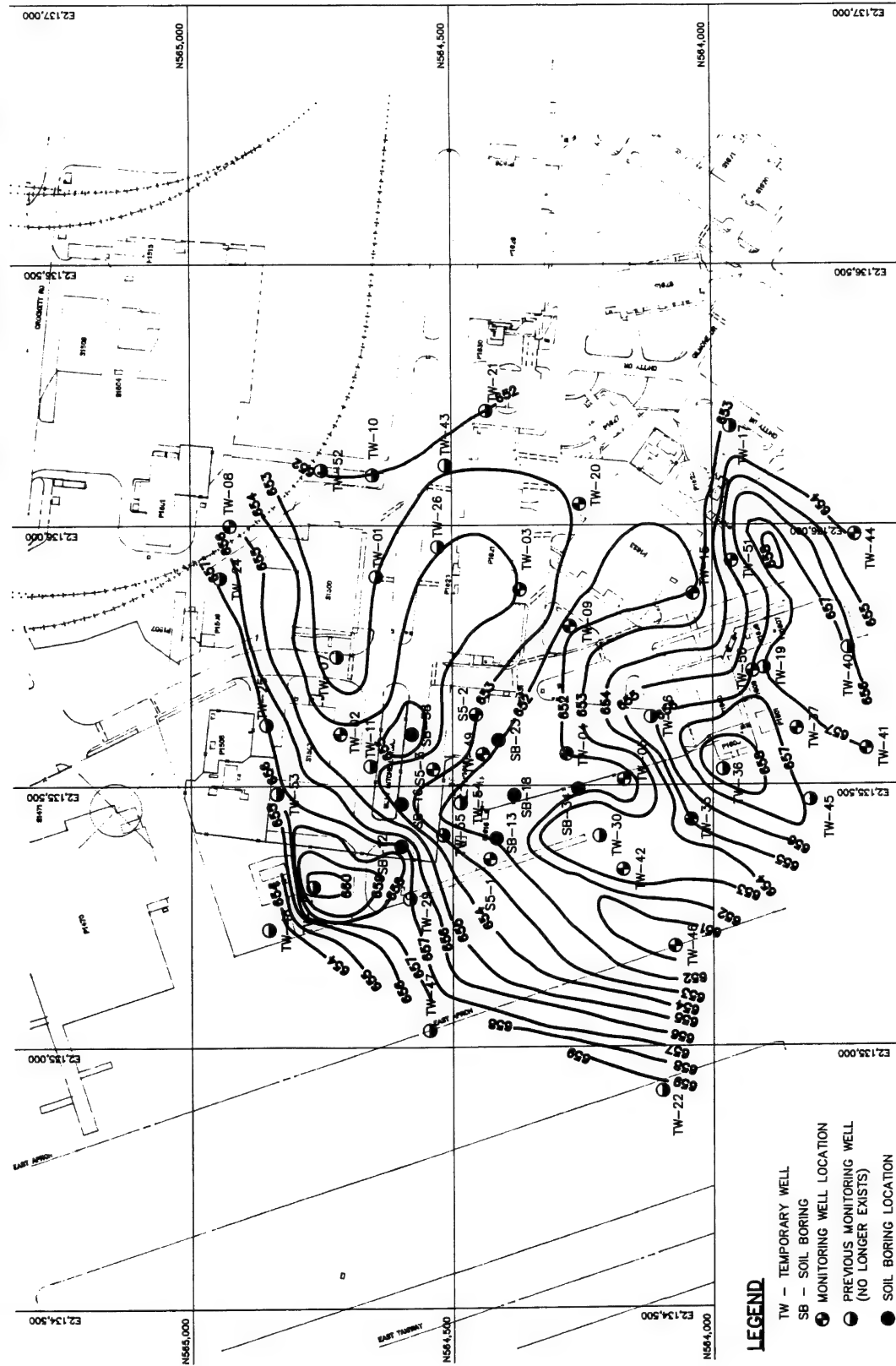
HALLIBURTON NUS
Environmental Corporation

3-9

CROSS SECTION C-C'
SITE S-5
KELLY AFB, SAN ANTONIO, TX

NOTES:

1. WATER LEVELS WERE TAKEN 10-27-90 UNLESS OTHERWISE NOTED.
2. ALL GEOLOGIC BOUNDARIES HAVE BEEN INTERPOLATED BETWEEN BORINGS AND ARE BEST APPROXIMATIONS. LITHOLOGIC DESCRIPTIONS ARE BASED UPON BORING LOGS. ACTUAL BOUNDARIES AND MATERIALS MAY DIFFER FROM THOSE SHOWN



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- - MONITORING WELL LOCATION
- - PREVIOUS MONITORING WELL (NO LONGER EXISTS)
- - SOIL BORING LOCATION

TOP OF NAVARRO CLAY ELEVATION MAP
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

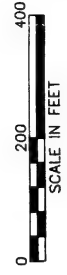
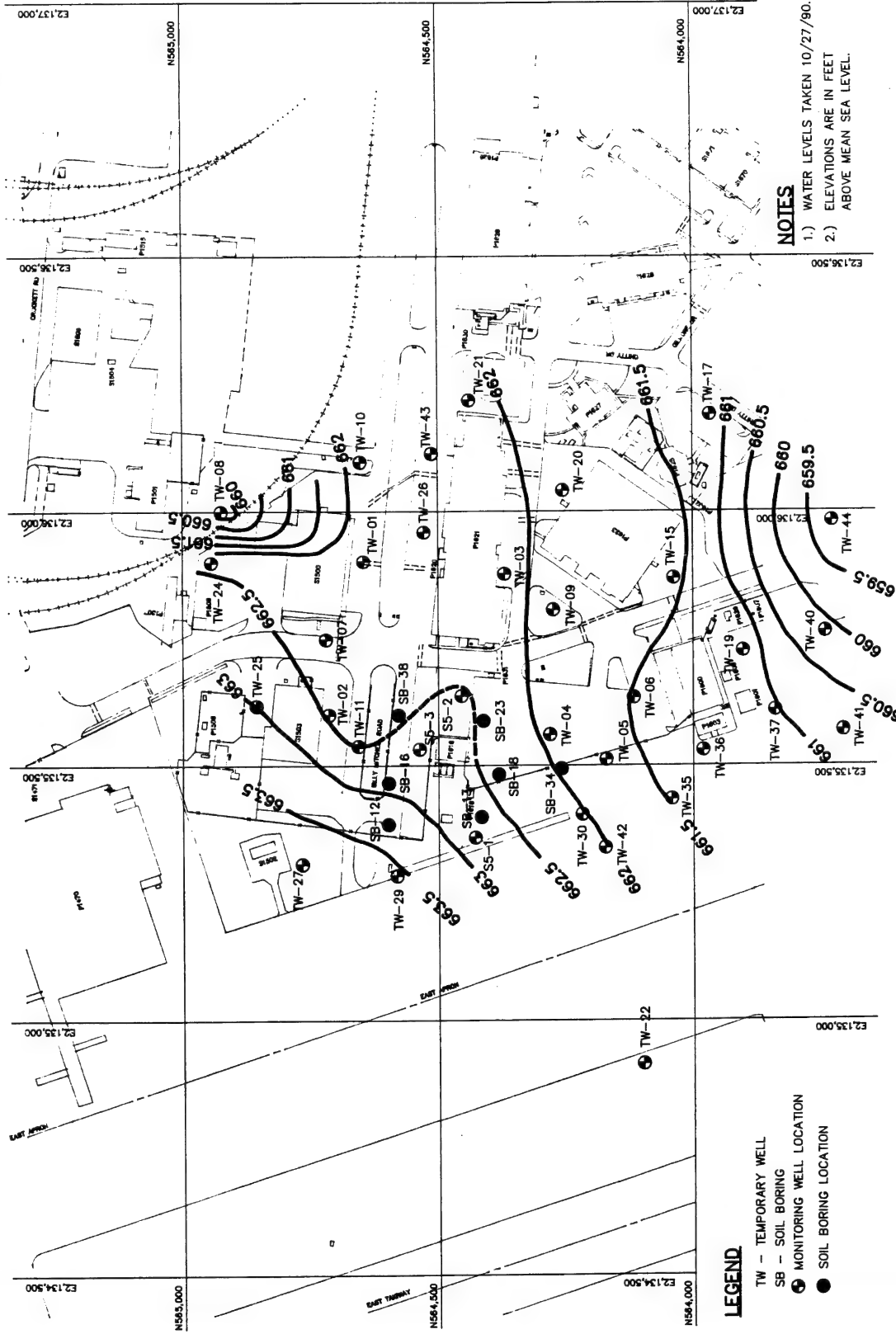


FIGURE 3-5



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION

NOTES

- 1.) WATER LEVELS TAKEN 10/27/90.
- 2.) ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL.

GROUNDWATER ELEVATION CONTOUR MAP (1990)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

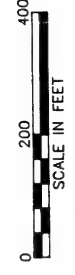


FIGURE 3-6

TABLE 3-1

WATER LEVEL AND HYDRAULIC CONDUCTIVITY READINGS (1991)
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Well Number	Elevation T.O.C.(1)	Date	Water (3)	Date	Water (3)	Date	Water (3)	Hydraulic Conductivity (K) Feet/Day
		06/03/91(2)	Elevation	06/05/91(2)	Elevation	07/18/91(2)	Elevation	
SS-1	686.95	NA	NA	22.78	664.17	22.68	664.27	12.31
SS-2	686.29	NA	NA	22.82	663.47	22.32	663.97	45.70
SS-3	686.51	NA	NA	23.20	663.31	22.61	663.90	99.03
W-01	682.88	19.79	663.09	19.81	663.07	19.32	663.56	12.80
W-02	684.31	21.11	663.20	21.12	663.19	20.63	663.68	29.13
W-03	682.09	19.10	662.99	19.13	662.96	18.66	663.43	44.84
W-04	682.72	20.13	662.59	20.10	662.62	19.75	662.97	53.70
W-05	681.44	19.01	662.43	19.00	662.44	18.70	662.74	44.06
W-06	681.83	19.87	661.96	19.89	661.94	19.62	662.21	40.98
W-07	683.38	20.31	663.07	20.23	663.15	19.82	663.56	NA(4)
W-08	682.75	19.58	663.17	19.62	663.13	19.02	663.73	31.27
W-09	682.27	19.60	662.67	19.63	662.64	19.19	663.08	59.26
W-15	680.57	18.11	662.46	18.20	662.37	17.76	662.81	33.01
W-20	681.13	18.56	662.57	18.57	662.56	18.12	663.01	88.02
W-21	682.10	19.21	662.89	19.21	662.89	18.59	663.51	11.93
W-35	680.63	18.76	661.87	18.77	661.86	18.52	662.11	118.83
W-37	678.20	16.70	661.50	16.72	661.48	16.43	661.77	109.88
W-41	678.15	16.78	661.37	16.70	661.45	16.52	661.63	NA(4)
W-42	682.42	19.98	662.44	19.99	662.43	19.70	662.72	25.02
W-43	683.61	20.52	663.09	20.75	662.86	20.20	663.41	21.48
W-44	678.93	16.08	662.85	16.11	662.82	15.52	663.41	59.42
W-45	679.03	17.47	661.56	17.47	661.56	17.20	661.83	NA(4)
W-46	681.13	18.93	662.20	18.92	662.21	18.68	662.45	22.63
W-47	684.23	21.12	664.11	20.10	664.13	19.79	664.44	198.05
W-48	685.94	21.45	664.49	21.45	664.49	21.10	664.84	132.04
W-49	683.73	20.62	663.11	20.64	663.09	20.19	663.54	43.21
W-50	679.61	17.65	661.96	17.67	661.94	17.34	662.27	39.61
W-51	680.57	18.25	662.32	18.20	662.37	17.75	662.82	30.87
W-52	682.71	19.63	663.08	19.65	663.06	19.13	663.58	22.63
W-53	684.24	20.21	664.03	18.20	666.04	19.75	664.49	55.27
W-54	684.95	23.10	661.85	NA	NA	21.32	663.63	NA(4)
W-55	684.39	20.34	664.05	20.38	664.01	20.02	664.37	22.63

- (1) Elevation of top of casing in feet above mean sea level.
 (2) Water level measured in feet below top of casing.
 (3) Elevation of water level in feet above mean sea level.
 (4) Test was not performed due to lack of sufficient depth of water.

present at the completion of the Phase 1 field activities. Figure 3-7 presents the potentiometric surface contours based on the 1991 data.

Based on the potentiometric surface maps, the groundwater flow direction across the site is generally to the south, with an apparent low point in the northeast in the vicinity of well TW-08. The hydraulic gradient across the site (measured from TW-48 to TW-41) averages 0.003 ft/ft. The gradient varies locally, however, and was estimated at 0.002 ft/ft between wells TW-25 and TW-17 and 0.008 ft/ft between wells S5-1 and TW-30.

Rising-head slug tests were performed on 28 wells during the Phase 2 field activities. Hydraulic conductivity results varied from 11.93 ft/day to 198.05 ft/day. The large variance in the conductivity results indicates the dissimilar nature of the alluvial gravels at different locations. The geometric mean of the conductivity results is 41.59 ft/day. Appendix C presents the raw data for all rising-head slug tests. Table 3-1 presents a summary of the hydraulic conductivity tests performed during Phase 2 of the field investigation (1991).

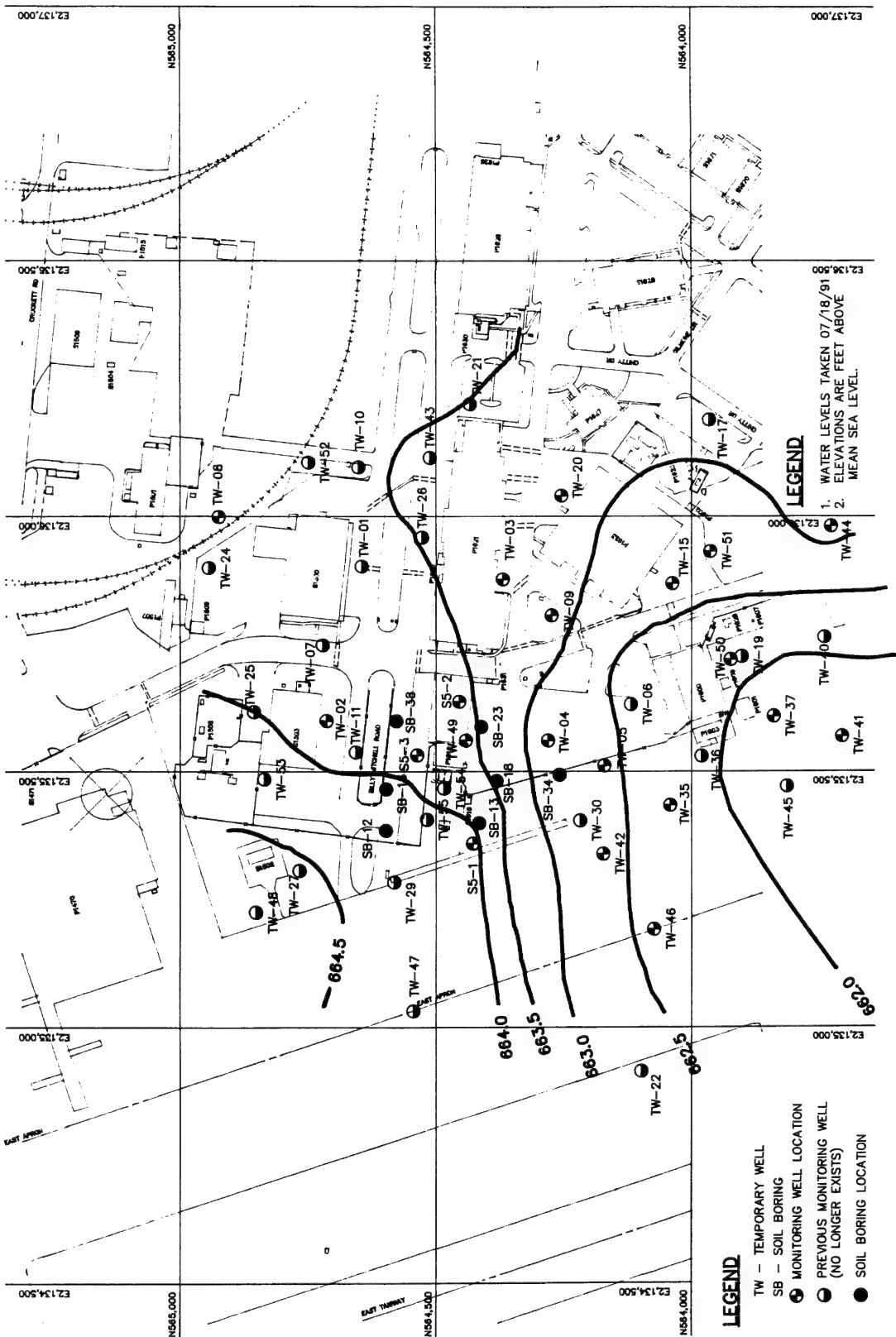


FIGURE 3-7

GROUNDWATER ELEVATION CONTOUR MAP (1991)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 INTRODUCTION

This section presents a summary of the chemical analytical results for the soil and groundwater samples collected during the investigation of Site S-5. In 1990, samples were collected for the initial site investigation, and in 1991, additional samples were collected to supplement the data gaps identified in the first report. Soil samples are discussed in Section 4.2 and analysis of the drill cuttings is discussed in Section 4.3. Section 4.4 presents a summary of the groundwater analytical results. The quality assurance/quality control samples (QA/QC) collected throughout both phases of the investigation are presented in Appendix D and the importance of these samples in data validation is presented in the Informal Technical Information Report (HALLIBURTON NUS, September 1991). All 1990 and 1991 sample locations are shown in Figure 2-1.

All of the fixed base laboratory results in the following sections were validated by HALLIBURTON NUS personnel. Field laboratory results were not validated. The data presented in this section are reduced to only the positive detections in the interest of readability. Details on the data base, such as sample detection limits and associated blanks are in Appendix D and the following reports:

- HALLIBURTON NUS, January 1991. Installation Restoration Program - Site Inspection Report.
- HALLIBURTON NUS, September 1991. Installation Restoration Program - Informal Technical Information Report - Analytical Data for Round 2 Sampling.

4.2 SUBSURFACE SOIL

4.2.1 1990 Investigation

Eight soil borings (SB-06, SB-12, SB-13, SB-16, SB-18, SB-23, SB-34, and SB-38) were drilled during the initial site investigation at the locations shown in Figure 2-1. Five or six samples were collected from each of the borings at depths between 4.5 and 29.5 feet. All samples were analyzed for target volatile organic compounds at the field laboratory and all lead and petroleum hydrocarbons analyses were performed in the HALLIBURTON NUS fixed base laboratory in Pittsburgh, Pennsylvania. Ten of the samples that were analyzed for target volatile organics in the field were subsequently sent to the

fixed base laboratory for volatile organics analysis using GC/MS. Table 4-1 presents summaries of the 1990 analytical results.

Several volatile organic chemicals (benzene, toluene, ethylbenzene, and 1,2-/1,4-dichlorobenzene) were detected in the samples analyzed in the field laboratory. However, the data from the fixed base laboratory failed to confirm the presence of these compounds. The six samples analyzed by the fixed base laboratory were found to contain only acetone (at a maximum concentration of 63 $\mu\text{g/kg}$ in duplicate samples from SB-23). The results from the fixed base laboratory are considered to be more reliable than those from the field laboratory because of the second column confirmation afforded by the mass spectrometer.

Data from the field laboratory revealed that toluene was the most frequently detected target volatile organic (25 of 41 samples). The maximum concentration of toluene (average of 4,600 $\mu\text{g/kg}$ in two duplicate samples) was found in soil boring SB-18 at a depth of 19.5 to 21.5 feet. In addition, soil samples collected from the same depth from borings SB-23 and SB-34 also contained toluene at average concentrations of 370 $\mu\text{g/kg}$ and 280 $\mu\text{g/kg}$, respectively. However, these data results were not confirmed by a second column. It should also be noted that no toluene was found in the groundwater samples analyzed in the fixed base laboratory.

The only other target volatile organic compounds detected during the field analysis were benzene, ethylbenzene, and 1,2-/1,4-dichlorobenzene. Benzene was found in 7 of 41 samples at a maximum concentration of 15 $\mu\text{g/kg}$ in boring SB-23 (at a depth of 24.5 to 26.5 feet). Benzene was also detected at an average concentration of 13 $\mu\text{g/kg}$ in duplicate samples collected from boring SB-23 from a depth of 19.5 to 21.5 feet. Ethylbenzene was found in 3 of 41 samples at a maximum concentration of 11 $\mu\text{g/kg}$ in boring SB-13 (24.5 to 26.5 feet), a sample that also contained the sole detection of dichlorobenzenes (20 $\mu\text{g/kg}$).

4.2.2 1991 Investigation

In 1991, two additional soil borings (SB-54 and SB-55) were used for collection of samples for chemical analysis. A total of 15 samples were collected from the two borings, six of which were analyzed at the fixed base laboratory and nine at the field laboratory. The samples analyzed in the field were analyzed only for the target volatile organics, and several samples collected from the zone at or below the water table were sent to the fixed base laboratory for additional analyses as described in Section 2.3. The 1991 field laboratory analytical results are summarized in Table 4-2 and the fixed base laboratory results are in Table 4-3.

TABLE 4-1

CHEMICAL-ANALYTICAL RESULTS - SUBSURFACE SOIL (1990)
FIELD/FIXED BASE LABORATORIES
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

SAN ANTONIO, TEXAS																				
Analyte(1)	SB-06					SB-12					SB-13					SB-16				
	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet(2)	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet(2)	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet(2)	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet(2)	24.5 Feet
Field Laboratory																				
Benzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12*	ND	ND	ND	ND	ND	8.1
Toluene	ND	ND	ND	300	8.1	ND	ND	ND	120*	6.1	19	ND	ND	160*	90	5.6	ND	ND	60	930
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	ND
1,2-Dichlorobenzene/ 1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	20	ND	ND	ND	ND	ND
Fixed-Based Laboratory																				
Lead	23	18	17	14	15	27	20	15	18*	18	28	13	20	14*	13	12	ND	12	10	9
Petroleum hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	250
Acetone (µg/kg)	NA	NA	NA	ND	NA	NA	NA	NA	ND*	NA	NA	NA	NA	ND*	NA	NA	NA	NA	NA	NA

TABLE 4-1
CHEMICAL-ANALYTICAL RESULTS - SUBSURFACE SOIL (1990)
FIELD/FIXED BASE LABORATORIES
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Analyte ⁽¹⁾	SB-18						SB-23						SB-34						SB-38					
	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet ⁽²⁾	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet ⁽²⁾	24.5 Feet	29.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet ⁽²⁾	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet	19.5 Feet ⁽²⁾	24.5 Feet	4.5 Feet	9.5 Feet	14.5 Feet
Field Laboratory																								
Benzene	9.8	ND	ND	ND	ND	ND	ND	ND	13*	15	ND	ND	ND	ND	ND	ND	11	ND	ND	ND	ND	13	ND	ND
Toluene	31	5.9	62	4,600*	ND	12	ND	ND	370*	52	ND	21	5.5	6	280*	9.7	20	ND	ND	ND	40*	140	ND	ND
Ethylbenzene	8.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene/ 1,4-Dichlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fixed-Base Laboratory																								
Lead	15	18	ND	17*	ND	11	6	11	12*	13	9	13	8	ND	13*	5	27	11	20	ND	ND	6.4	ND	ND
Petroleum hydrocarbons	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	310	ND	ND	ND	ND
Acetone (µg/kg)	NA	NA	NA	NA	NA	NA	NA	NA	63*	NA	NA	NA	NA	NA	38*	NA	NA	NA	NA	NA	NA	NA	NA	NA

NA Not analyzed.

ND Not detected.

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

(1) Target volatile organics analyzed in field laboratory; lead and petroleum hydrocarbons analyzed in fixed base laboratory.

(2) Approximate depth of the water table.

TABLE 4-2
CHEMICAL-ANALYTICAL RESULTS - SUBSURFACE SOIL (1991)
FIELD LABORATORY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Analyte ⁽¹⁾	SB-54 (µg/kg)					SB-55 (µg/kg)			
	0.5 Feet	4.0 Feet	9.0 Feet	14.0 Feet	24.0 Feet	0.5 Feet	4.0 Feet	9.0 Feet	14.0 Feet
Toluene	240	ND	190*	240	ND	340	ND	ND	180
Ethylbenzene	ND	ND	ND	ND	100	640	200	400	650
Tetrachloroethene	ND	60	120*	ND	240	ND	29	ND	ND

ND Not detected.

(1) Target volatile organics analyzed in field laboratory.

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

TABLE 4-3
CHEMICAL-ANALYTICAL RESULTS - SUBSURFACE SOIL (1991)
FIXED BASE LABORATORY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Analyte ⁽¹⁾	SB-54			SB-55		
	18 Feet	26 Feet	29 Feet	19 Feet	24 Feet	29 Feet
	($\mu\text{g/kg}$)	($\mu\text{g/kg}$)	($\mu\text{g/kg}$)	($\mu\text{g/kg}$)	($\mu\text{g/kg}$)	($\mu\text{g/kg}$)
Acetone	561	ND	ND	1,040	ND	191
2-Butanone	ND	ND	10	ND	7	20
Chloroform	8	ND	ND	ND	ND	ND
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Lead	10*	6.5	10	NA	7.0	NA
Petroleum Hydrocarbons	729	ND	ND	NA	ND	NA

NA Not analyzed.

ND Not detected.

(1) Volatile organics analyzed in fixed base laboratory.

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

Of the target volatile organics, only toluene, ethylbenzene, and tetrachloroethene were found in any of the field-analyzed samples. Toluene was found in four of nine samples at a maximum concentration of 340 µg/kg in boring SB-55 (0.5 to 2.5 feet), while the maximum concentration of ethylbenzene (650 µg/kg) was found at a depth of 14 to 16 feet in the same boring. Tetrachloroethene was found at a maximum concentration of 240 µg/kg in boring SB-54 (24 to 26 feet).

None of the target analytes was confirmed by the fixed base laboratory analyses. Acetone, 2-butanone (methyl ethyl ketone), and chloroform were found in several samples. The maximum concentrations of acetone (1,040 µg/kg) and 2-butanone (20 µg/kg) were found in boring SB-55, while the maximum concentration of chloroform (8 µg/kg) was found in boring SB-54.

No overall trends were noted in the data with the exception of the previously mentioned maxima at or near the water table, which ranges in depth from about 16 to 21 feet. This fact will be discussed in more detail in Section 5.4.

All but four of the soil samples collected in 1990 were also found to contain lead at concentrations ranging from 5 to 28 mg/kg. In general, the results of the lead analyses were not indicative of any trend of lead contamination in the soil, however, it should be noted that at several locations (SB-06, SB-12, SB-13, and SB-38), the greatest concentrations of lead were found at the 4.5- to 6.5-foot depth. This depth may be related to the depth of Avgas distribution lines.

In 1991, only four of the six samples sent to the fixed base laboratory were analyzed for lead and petroleum hydrocarbons. Lead was detected in all four samples at concentrations ranging from 6.5 to 10 mg/kg. The maximum concentration of lead was 10 mg/kg, (found in SB-54 in both the 18- to 20-foot sample and the 29- to 31-foot sample).

Petroleum hydrocarbons were detected in only two borings in 1990 (SB-16 and SB-38) at the 24.5- to 26.5-foot depth. These concentrations were 250 and 310 mg/kg, respectively. In 1991, petroleum hydrocarbons were found only in the 18- to 20-foot sample collected from boring SB-54 at a concentration of 729 mg/kg.

Several samples were also analyzed for semivolatile organics and/or pesticides/PCBs in the field laboratory and/or the fixed base laboratory in both 1990 and 1991. However, none of these analytes was found to be present, therefore the results are not tabulated in the preceding tables.

4.3 WASTE SAMPLES

Drill cuttings generated during the drilling of the 1990 soil borings and monitoring wells were collected and stored in three dumpsters on base. To determine whether the cuttings were considered to be hazardous under RCRA, one composite sample was collected from the three dumpsters and subjected to the TCLP leaching procedure and analysis for the required volatiles, semivolatiles, and metals. Only positive detections are shown in Table 4-4. Only one volatile organic (benzene) and two metals (silver and barium) were detected in the extract from sample TCLP-2, and all were below their respective (RCRA) regulatory levels. No other positive detections were noted by the laboratory.

In 1991, additional composite cuttings samples were collected from the dumpsters used for onsite storage of drill cuttings, as follows:

- One sample from GG dumpster for TPH (WS01)
- One sample from three BFI dumpsters for TPH (WS02)
- One sample from all four dumpsters for TCLP, lead, BTEX, and TOX (WS01/WS02)

Texas Department of Health requirements (TDH, February 4, 1991) were used to develop the sampling and analytical protocols. These results are presented in Table 4-4.

Disposal in a Type I landfill requires special TDH approval unless the limits shown in Table 4-4 are met. These standards are the composite of the standards for soils contaminated with automotive gasoline, diesel fuel, and used motor oil. While the total concentrations of BTEX (benzene, toluene, ethylbenzene, and xylenes), total lead, leachable metals, and TPH are all below the TDH limits, the measured concentration of total organic halogens (50 mg/kg) equals the TDH requirement. In addition, the concentration of leachable benzene (TCLP/ZHE) cannot exceed 0.25 mg/L.

4.4 GROUNDWATER

4.4.1 1990 Investigation

In 1990, 29 monitoring wells, including the three original onsite wells (S5-1, S5-2, and S5-3), were sampled by HALLIBURTON NUS personnel. Two other existing wells were dry at that time. The samples were analyzed for target volatile organics in the field laboratory. Second column confirmation was performed in the fixed base laboratory in Pittsburgh, as well as analysis for lead and petroleum hydrocarbons. In addition, six samples were also analyzed at the field laboratory for target semivolatile organic chemicals. Table 4-5 presents a summary of the 1990 analytical results.

TABLE 4-4

**ANALYSIS OF DRILL CUTTINGS FOR DISPOSAL IN TYPE I LANDFILL (1990/1991)⁽¹⁾
FIXED BASE LABORATORY**

SITE S-5

**KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS**

Analyte	1990 Sample- TCLP-2	1991 Sample- Composite (WS01/WS02)	TDH Limit for Type I Landfill	RCRA Limit for Toxicity Characteristic
Benzene	0.006 mg/L	ND(0.05 mg/L)	0.25 mg/L	0.50 mg/L
Barium (TCLP)	1.0 mg/L	0.98 mg/L	None	100 mg/L
Lead (TCLP)	ND (0.05 mg/L)	ND (0.03 mg/L)	2.5 mg/L	5 mg/L
Silver (TCLP)	0.03 mg/L	0.02 mg/L	None	5 mg/L
BTEX ⁽²⁾	NA	0.001 mg/kg	150 mg/kg	None
Total Organic Halogens	NA	50 mg/kg	50 mg/kg	None
Lead	NA	83 mg/kg	250 mg/kg	None
Total Petroleum Hydrocarbons	NA	35 mg/kg - WS01 30 mg/kg - WS02	600 mg/kg	None

NA Not analyzed

ND Not detected at detection limits shown in parentheses

(1) Only positive results are shown in this table.

(2) Benzene, toluene, ethylbenzene, and total xylenes.

TABLE 4-5

CHEMICAL-ANALYTICAL RESULTS - GROUNDWATER (1990)
FIELD/FIXED BASE LABORATORIES
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Analyte ⁽¹⁾	TW-01	TW-02	TW-03	TW-04	TW-05	TW-06	TW-07	TW-08	TW-09	TW-10	TW-11	TW-15	TW-17	TW-19	TW-20	TW-21
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Field Laboratory																
Benzene	ND	ND	200	28	34	ND	ND	20	14	ND	ND	ND	ND	17	ND	ND
Toluene	13	ND	150	8.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12*	ND	290	ND	5
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	58	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	19	31	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	19	ND	ND	ND	ND	ND	ND	ND	ND
Fixed Base Laboratory	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Petroleum Hydrocarbons	2.5	ND	82	2.6	110	1.2	3	ND	2.6	ND	4.0	ND	NA	ND	ND	ND
Lead (Dissolved) (µg/L)	3	ND	4	ND	20	17	7	ND	ND	ND	ND	ND	ND	ND	ND	ND

TABLE 4-5
CHEMICAL-ANALYTICAL RESULTS - GROUNDWATER (1990)
FIELD/FIXED BASE LABORATORIES
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Analyte ⁽¹⁾	TW-24	TW-25	TW-26	TW-27	TW-29	TW-30	TW-35	TW-36	TW-37	TW-41	TW-42	TW-43	TW-44	SS-1-A	SS-2-A	SS-3-A
Field Laboratory	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Benzene	ND	ND	34	ND	ND	43*	ND	ND	10	ND	18	ND	ND	750	1,100	53
Toluene	ND	ND	ND	ND	58*	38*	ND	ND	ND	ND	ND	ND	ND	140	350	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	130	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	36	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	6.7	14*	ND	ND	ND	ND	ND	ND	ND	ND	58	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	ND	ND	21*	21	ND	26	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fixed Base Laboratory	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Petroleum Hydrocarbons	ND	ND	0.9	ND	6	2.8*	4.4	10.3	7.4	0.6	6.6	0.3	ND	27	10	13
Lead (Dissolved) (µg/L)	ND	ND	23	ND	3	3*	ND	2	ND	ND	4	ND	3	7	33	28

NA Not analyzed.
ND Not detected.

(1) Target volatile organics analyzed in field laboratory followed by second column confirmation in fixed base laboratory; lead and petroleum hydrocarbons analyzed in fixed base laboratory.

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

Several contaminant isoconcentration contour maps were prepared for the April 1991 Site Investigation Report (HALLIBURTON NUS, April 1991). These figures graphically illustrate the data shown in Table 4-5. Isoconcentration maps are presented for benzene, toluene, petroleum hydrocarbons, dissolved lead, tetrachloroethene (PCE), trichloroethene (TCE), and trans-1,2-dichloroethene (DCE). The pattern of groundwater contamination appeared to indicate the presence of two distinct source areas: the Site S-5 tank farm at Building 1618 and an unknown source south of Building 1600. Additional studies are currently being performed in the vicinity of the Building 1600 source area.

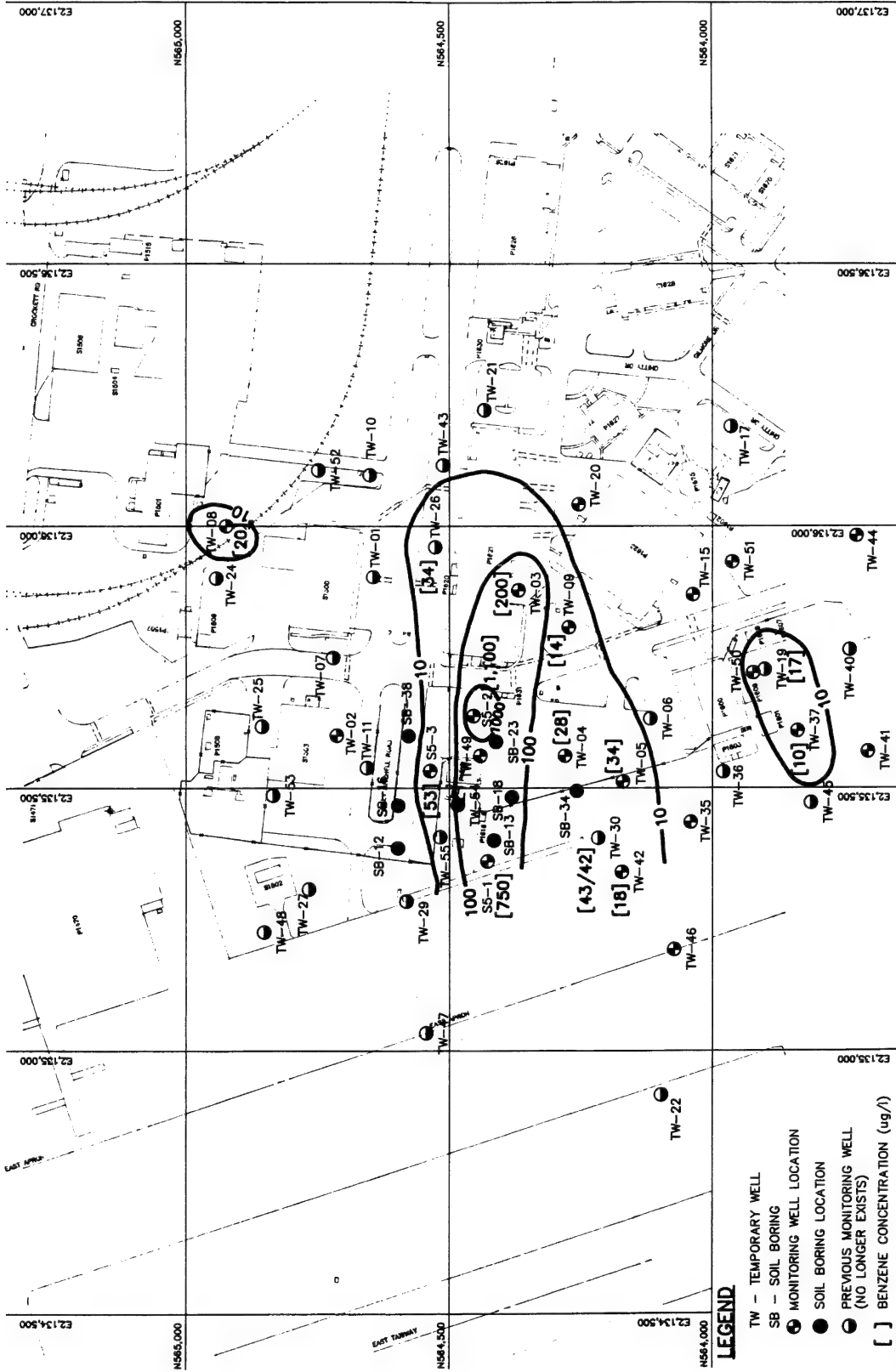
The compounds associated with fuels (benzene, toluene, petroleum hydrocarbons, and lead) exhibit a similar pattern of occurrence, with the primary plume extending eastward from the Building 1618 tank farm.

The highest concentrations of benzene were detected in wells S5-1 (750 $\mu\text{g/L}$) and S5-2 (1,100 $\mu\text{g/L}$). These wells also contained the highest concentrations of toluene (140 $\mu\text{g/L}$ and 350 $\mu\text{g/L}$, respectively). These contaminants are dispersed down and cross gradient from the tank farm. Benzene was also detected in the Building 1600 area as a separate plume. Isoconcentration contour maps for benzene and toluene are presented in Figures 4-1 and 4-2, respectively.

The highest concentrations of petroleum hydrocarbons were detected in wells in the immediate vicinity of and east of the Building 1618 tank farm, including well S5-1 (27 mg/L), S5-2 (10 mg/L), S5-3 (13 mg/L), and TW-03 (82 mg/L), as well as in individual wells farther south including wells TW-05 (110 mg/L) and TW-36 (10.3 mg/L). The petroleum hydrocarbons plume (defined as concentrations greater than 1 mg/L) appears to extend across both source areas, extending approximately 600 feet east and 750 feet south of the tank farm, as shown in Figure 4-3.

The highest concentrations of dissolved lead were detected in wells S5-2 (33 $\mu\text{g/L}$), S5-3 (28 $\mu\text{g/L}$), and TW-26 (23 $\mu\text{g/L}$). A second area of higher dissolved lead concentrations was located farther south in the vicinity of wells TW-05 (20 $\mu\text{g/L}$) and TW-06 (17 $\mu\text{g/L}$). Figure 4-4 presents estimated isoconcentration contours for dissolved lead. All dissolved lead concentrations were below the previous Safe Drinking Water Act Maximum Contaminant Level (MCL) of 50 $\mu\text{g/L}$, but several exceed the current action level of 15 $\mu\text{g/L}$ (as described in Table 6-4).

The chlorinated solvents PCE, TCE, and DCE exhibit a different pattern of contamination than the fuel-related constituents. The maximum detected concentration of PCE was 290 $\mu\text{g/L}$ in well TW-19. PCE was also detected in nearby wells TW-37 and TW-15 at concentrations of 36 $\mu\text{g/L}$ and 13 $\mu\text{g/L}$,



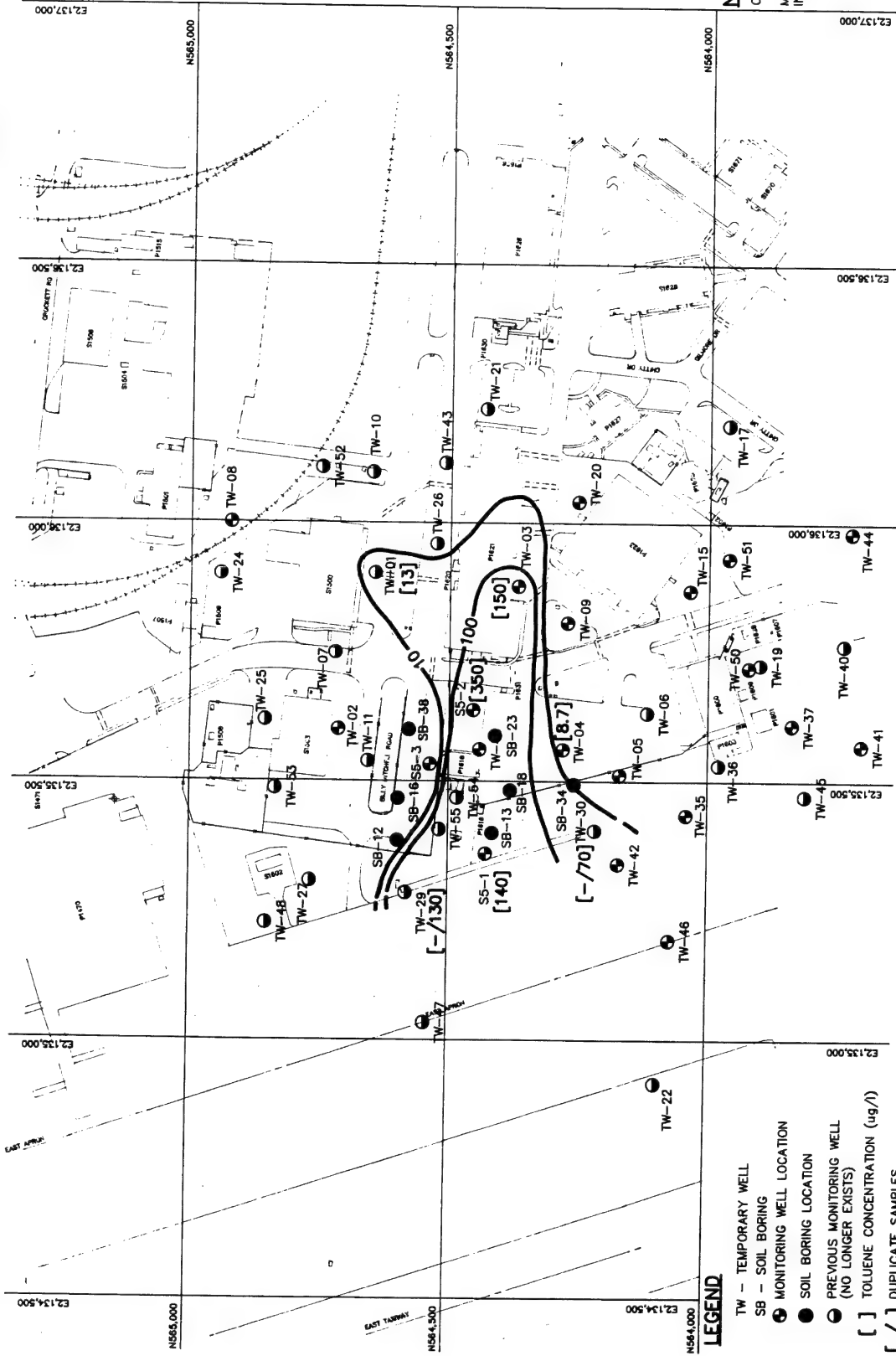
NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE BENZENE NOT DETECTED.

FIGURE 4-1



BENZENE ISOCONCENTRATION MAP (1990)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX



NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE TOLUENE NOT DETECTED.

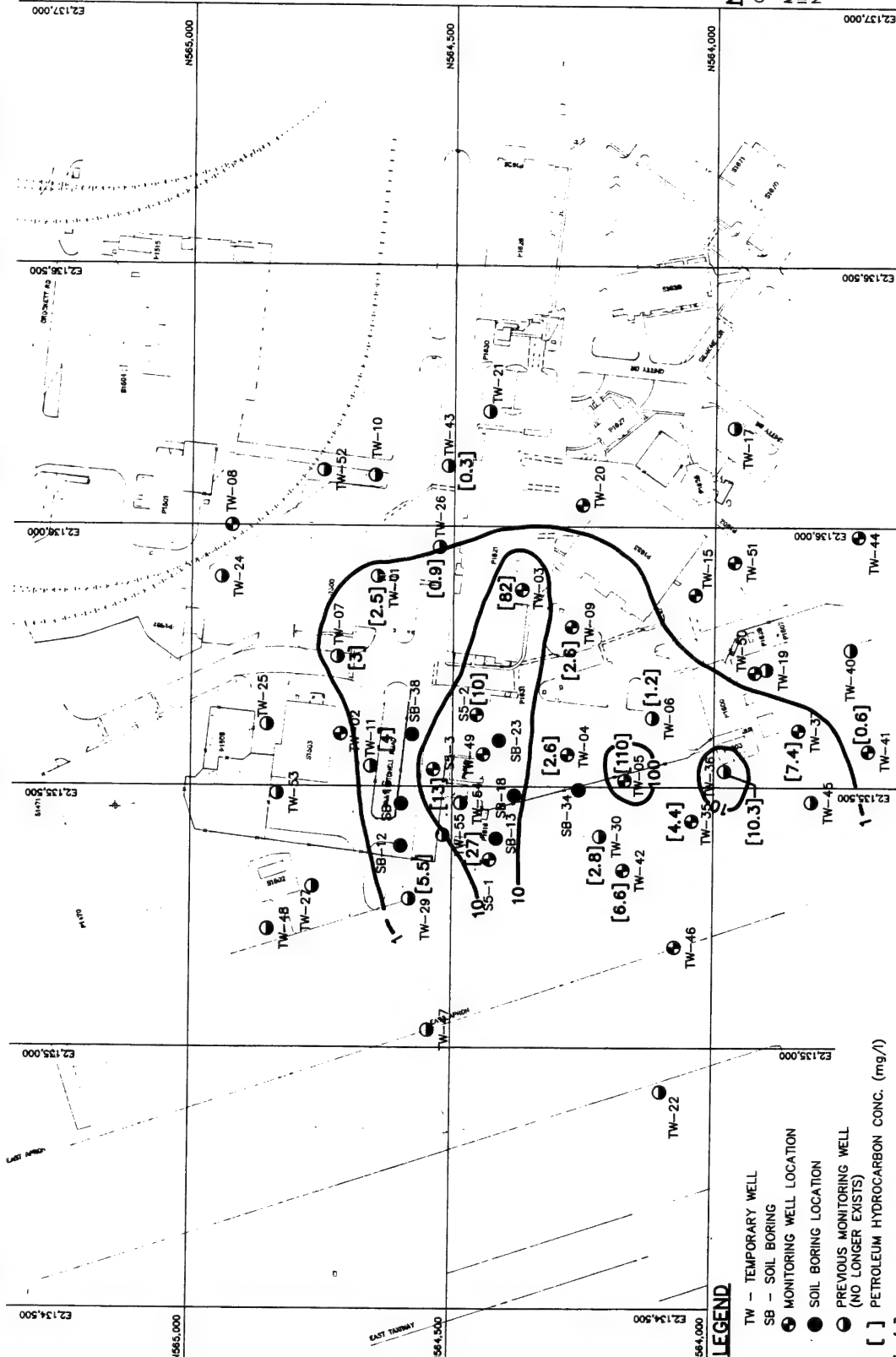
FIGURE 4-2

TOLUENE ISOCONCENTRATION MAP (1990)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- PREVIOUS MONITORING WELL (NO LONGER EXISTS)
- [] TOLUENE CONCENTRATION (ug/l)
- [/] DUPLICATE SAMPLES



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- PREVIOUS MONITORING WELL (NO LONGER EXISTS)
- [] PETROLEUM HYDROCARBON CONC. (mg/l)
- [/] DUPLICATE SAMPLES

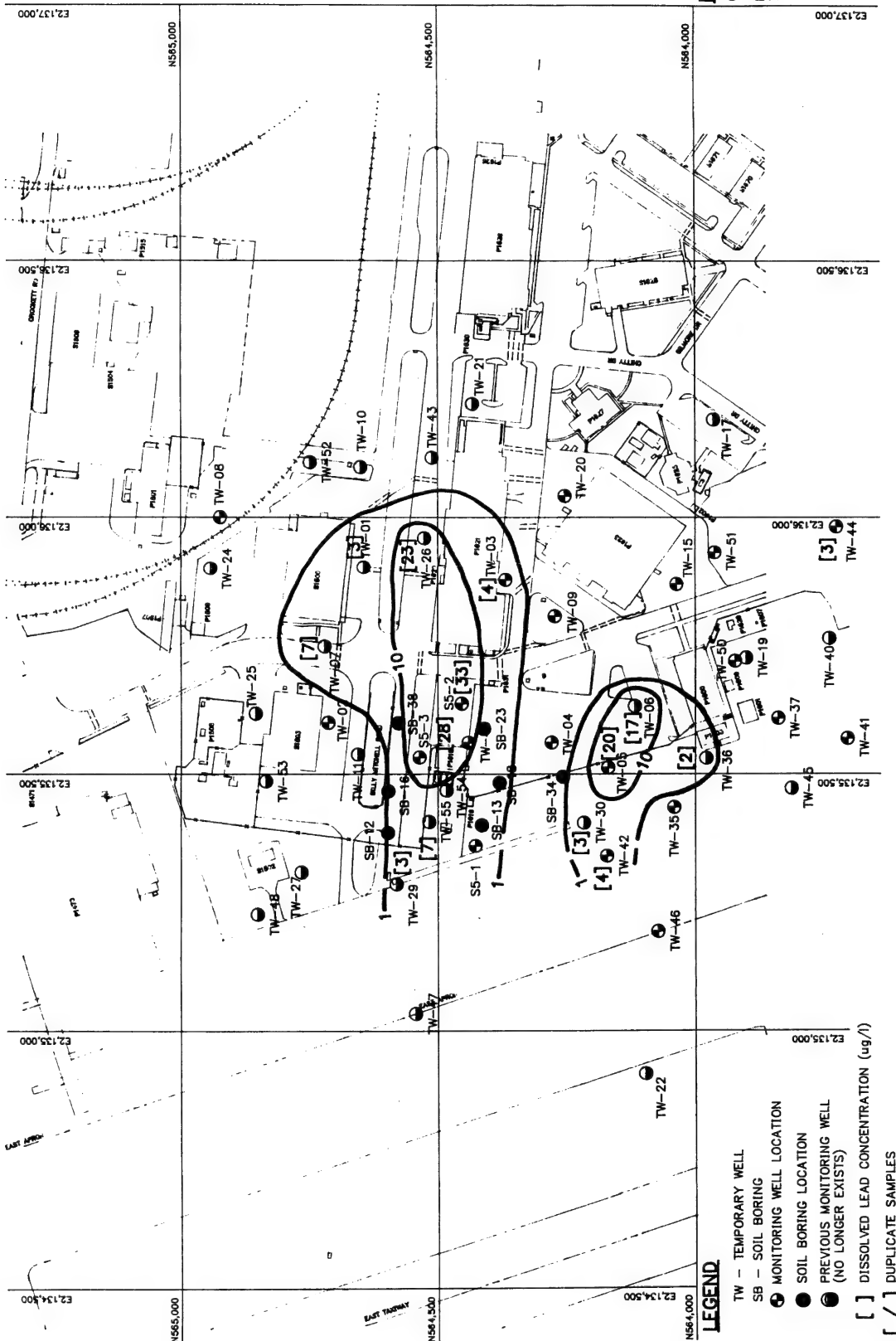
NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE PETROLEUM HYDROCARBONS
NOT DETECTED.

PETROLEUM HYDROCARBON ISOCONCENTRATION MAP (1990)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

FIGURE 4-3





LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- - MONITORING WELL LOCATION
- - SOIL BORING LOCATION
- - PREVIOUS MONITORING WELL (NO LONGER EXISTS)
- [] - DISSOLVED LEAD CONCENTRATION (ug/l)
- [/] - DUPLICATE SAMPLES

NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE DISSOLVED LEAD NOT DETECTED.

FIGURE 4-4

DISSOLVED LEAD ISOCONCENTRATION MAP (1990) SITE S-5 KELLY AIR FORCE BASE, SAN ANTONIO, TX



respectively. These wells are located in the vicinity of Building 1600. PCE was also detected in the easternmost well (TW-21) at a concentration of 5 µg/L. Figure 4-5 illustrates the PCE plume at Site S-5.

TCE was also detected in well TW-19 (58 µg/L), which is located near Building 1600. The only other detections of TCE were along the flightline northwest of the tank farm in wells TW-27 (6.7 µg/L) and TW-29 (14 µg/L). These results, as shown in Figure 4-6, potentially indicate a second, distinct source of TCE.

Trans-1,2-dichloroethene (DCE) was detected in the area south of Building 1600 in well TW-37 at a concentration of 26 µg/L. In addition, DCE was found in the vicinity of the parking lot between Buildings 1600 and 1618 at concentrations ranging from 19 µg/L in well TW-04 to 31 µg/L in well TW-05. Neither TCE nor PCE were detected in this area. Figure 4-7 contains the isoconcentration contour map for DCE.

No semivolatile organic chemicals were detected in any of the wells in 1990.

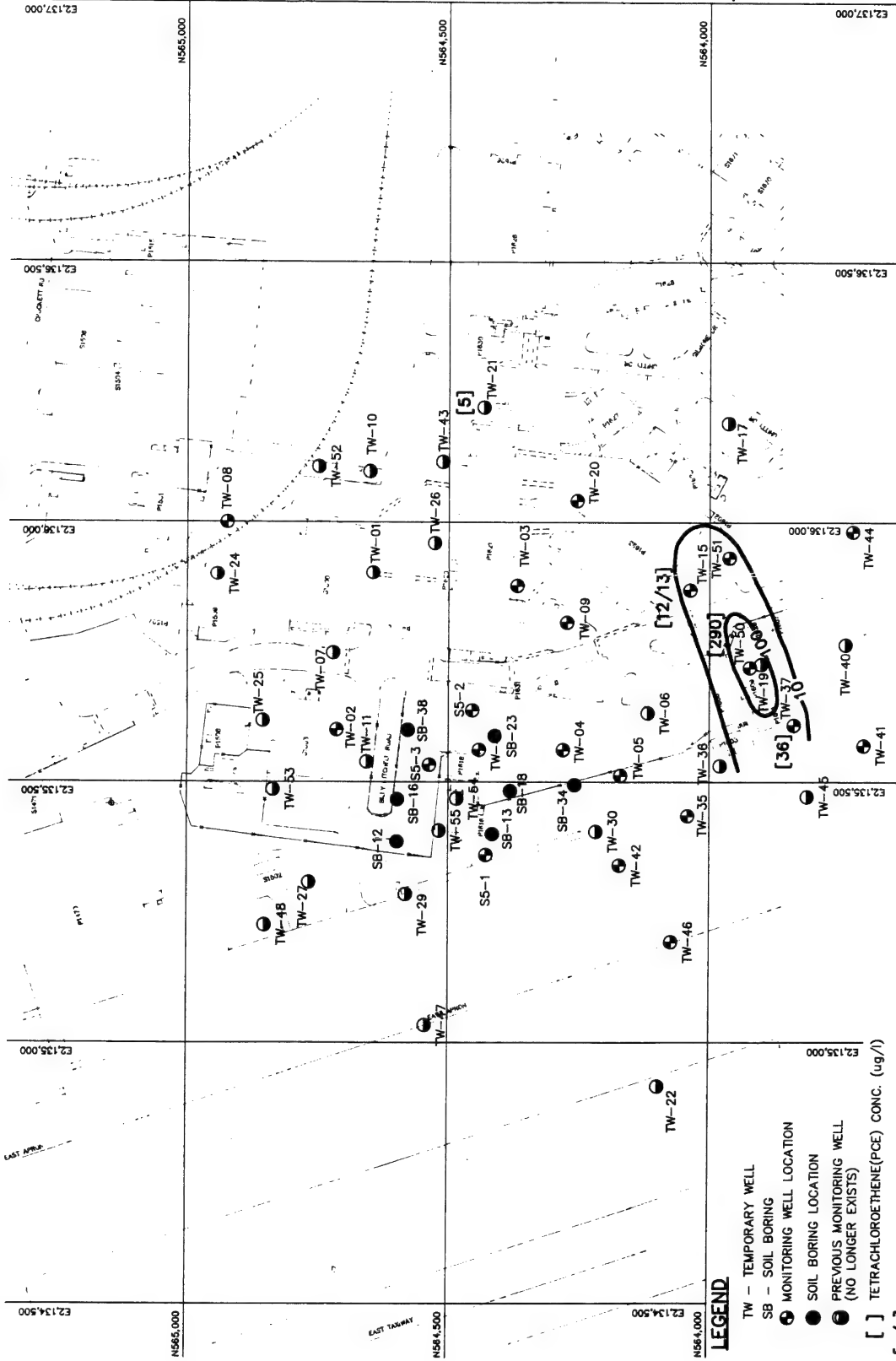
4.4.2 1991 Investigation

In 1991, 11 additional temporary wells were installed. These and 21 of the existing wells were sampled and analyzed for volatile organics. The volatiles were analyzed by both the field laboratory and the fixed base laboratory. Tables 4-6 and 4-7 summarize the 1991 field and fixed base laboratory analytical results, respectively.

In general, the 1991 analytical results exhibit similar patterns of contamination as the 1990 data, however the results were generally lower than those measured by the field laboratory in 1990. Possible reasons for the decrease in contamination from 1990 to 1991 include dilution of the groundwater over time, dispersion of the plume, and degradation of the contaminants within the plume. Due to the extremely complex nature of the surficial aquifer, the number of potential historical sources, and the number of years that the plume(s) has had time to migrate, it is not possible to determine the source of the various positive detections that are not obviously related to the Building 1618 fuel farm. The results for several chemicals are presented on a series of isoconcentration contour maps.

Figure 4-8 presents isoconcentration contours for benzene that were created from the 1991 data. The maximum concentration detected was 940 µg/L, but three other wells in the tank farm area also contained benzene at concentrations greater than 100 µg/L. Two small outlying areas of benzene at concentrations greater than the MCL (5 µg/L) were noted in the northern portion of the study area (at

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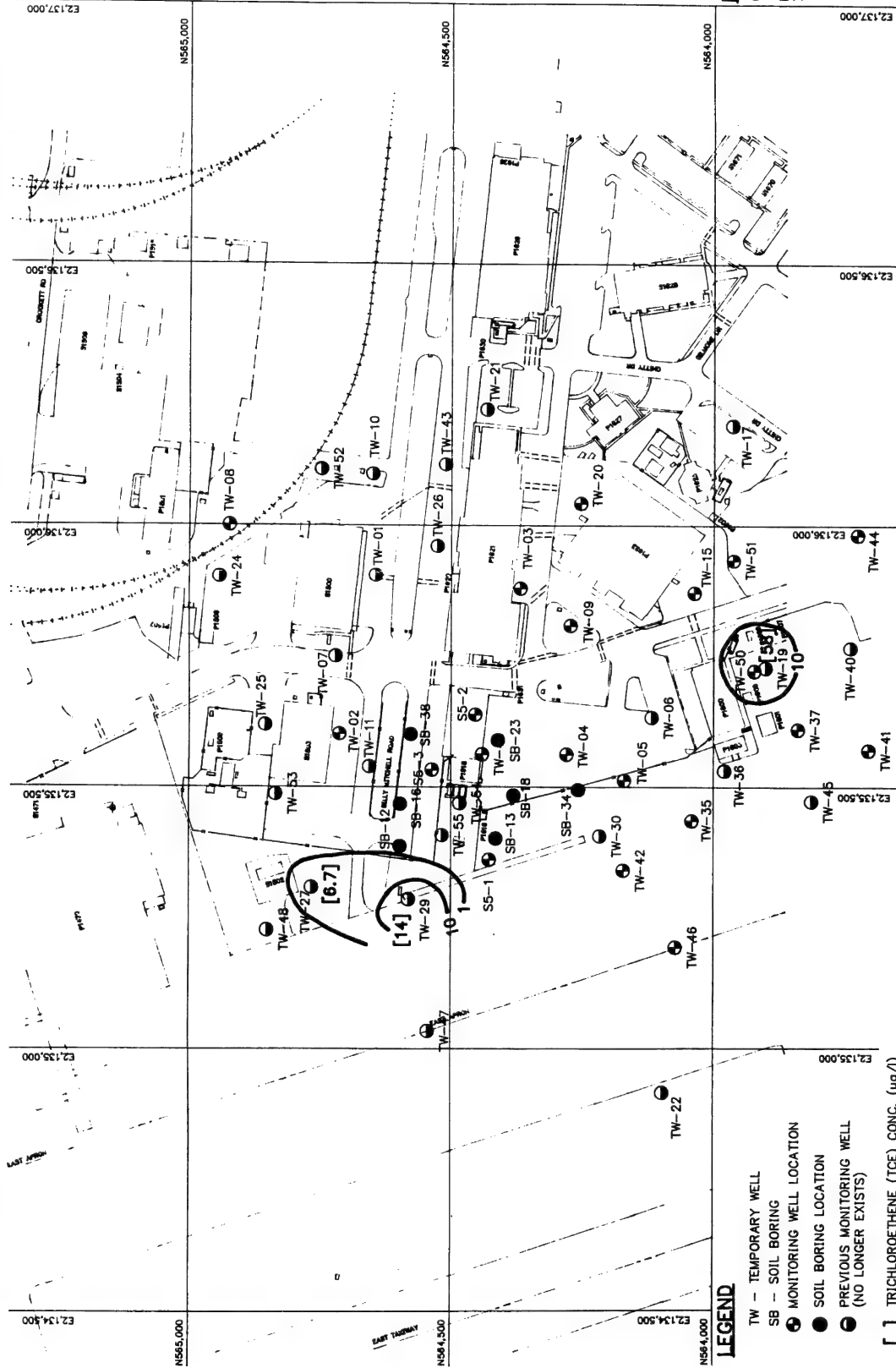
NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE PCE NOT DETECTED.

FIGURE 4-5

PCE ISOCONCENTRATION MAP (1990) SITE S-5 KELLY AIR FORCE BASE, SAN ANTONIO, TX





NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE TCE NOT DETECTED.

FIGURE 4-6

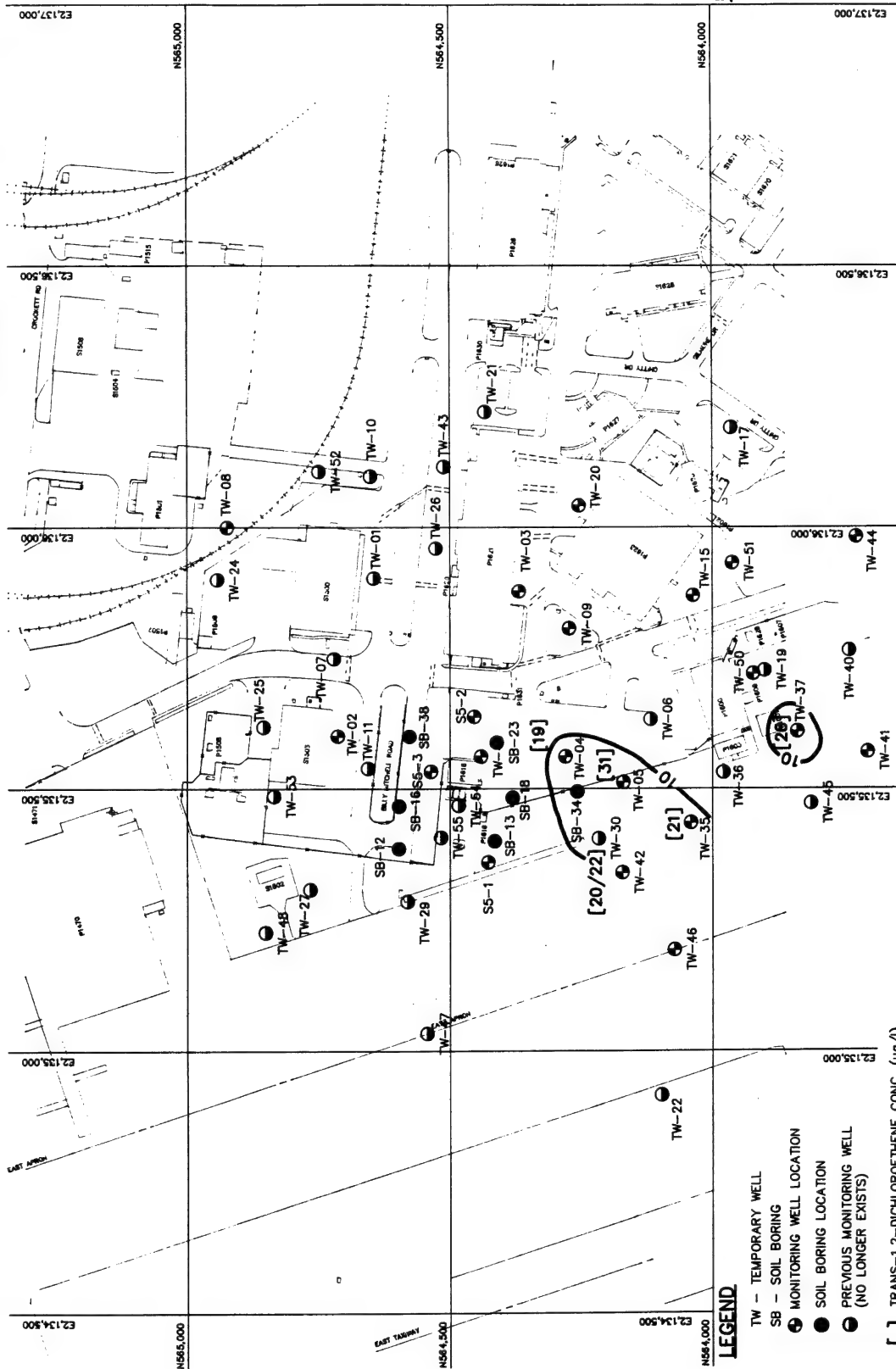
TCE ISOCONCENTRATION MAP (1990)

SITE S-5

KELLY AIR FORCE BASE, SAN ANTONIO, TX

0 200 400
SCALE IN FEET





NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE TRANS-1,2-DICHLOROETHENE
NOT DETECTED.

FIGURE 4-7

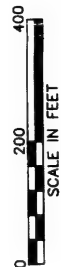


4-27

TRANS-1,2-DCE ISOCONCENTRATION MAP (1990)

SITE S-5

KELLY AIR FORCE BASE, SAN ANTONIO, TX



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- PREVIOUS MONITORING WELL (NO LONGER EXISTS)

[] TRANS-1,2-DICHLOROETHENE CONC. (ug/l)

[/] DUPLICATE SAMPLES

TABLE 4-6

CHEMICAL-ANALYTICAL RESULTS - GROUNDWATER (1991)($\mu\text{g/L}$)
 FIELD LABORATORY
 SITE S-5
 KELLY AIR FORCE BASE
 SAN ANTONIO, TEXAS

Analyte ⁽¹⁾	TW-45	TW-46	TW-47	TW-48	TW-49	TW-50	TW-51	TW-52	TW-53	TW-54	TW-55
Tetrachloroethene	19	ND	ND	ND	ND	4,200*	ND	ND	ND	ND	ND
Trichloroethene	ND	61	120	6.6	ND	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	12	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	19	7.4	ND	160	180

ND Not detected.

⁽¹⁾ Target volatile organics analyzed in the field laboratory.

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

TABLE 4-7

CHEMICAL-ANALYTICAL RESULTS - GROUNDWATER (1991)

FIXED BASE LABORATORY

SITE S-5

KELLY AIR FORCE BASE

SAN ANTONIO, TEXAS

Analyte	TW-01	TW-02	TW-03	TW-04	TW-05	TW-06	TW-07	TW-08	TW-09	TW-15	TW-20	TW-21	TW-35	TW-37	TW-41	TW-42
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Acetone	ND	ND	ND	ND	72	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone	ND	ND	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	ND	ND	29	16	27	ND	ND	34	ND	ND	ND	ND	ND	ND	ND	8
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	3	ND	ND	ND	ND	ND	3*	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	ND	3	4	ND	ND	ND	ND	3	ND	ND	8	3	ND	3
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	64	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	13	ND	ND	ND	ND	ND	ND	ND	11	27	21	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	610	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	33	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	2.5*	ND	3.5*	ND	ND	ND	ND	ND
Carbon disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	ND
Vinyl acetate	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	25
2-Methylphenol	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Petroleum Hydrocarbons	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

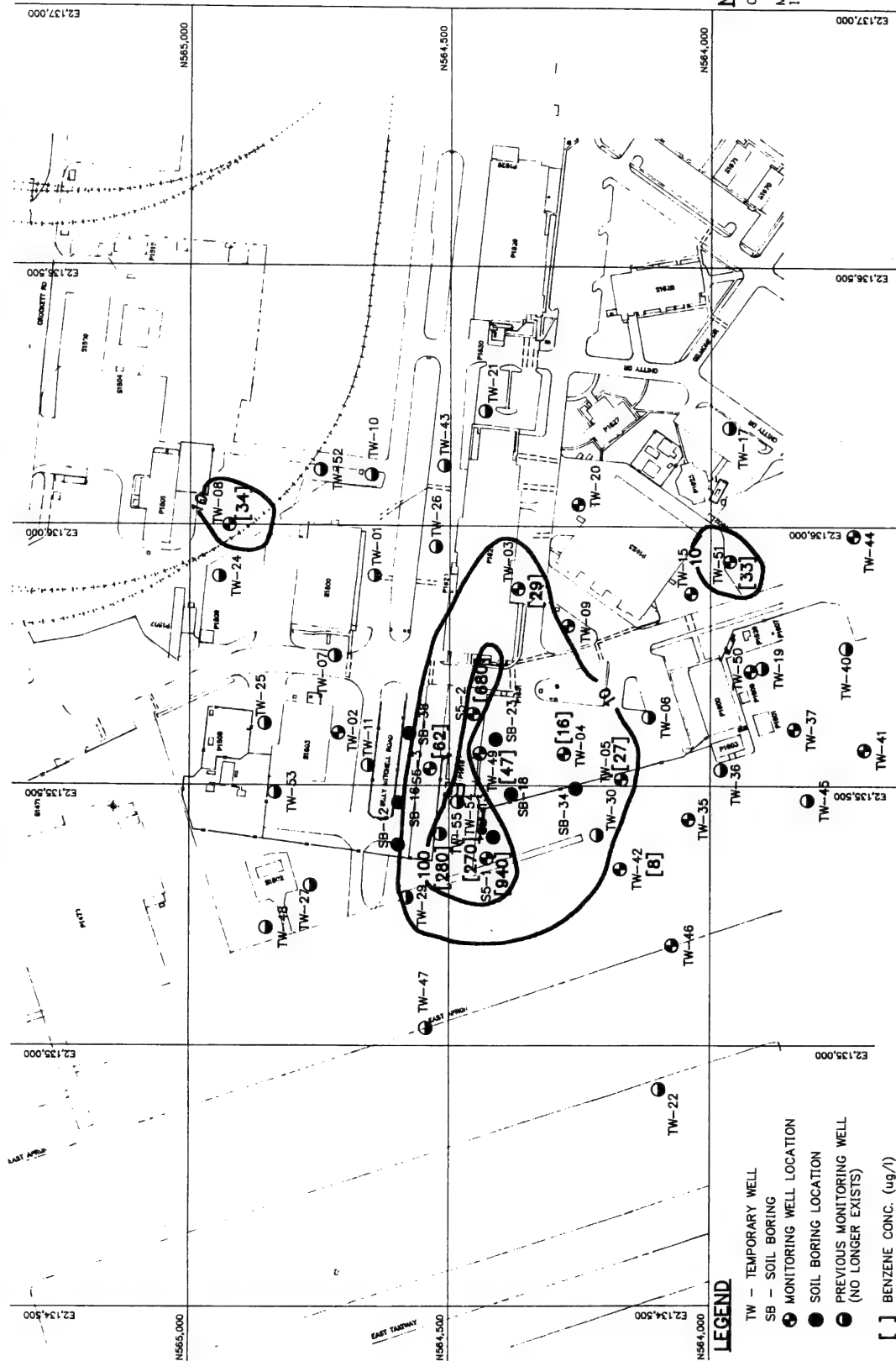
TABLE 4-7
CHEMICAL-ANALYTICAL RESULTS - GROUNDWATER (1991)
FIXED BASE LABORATORY
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

Analyte	TW-43	TW-44	TW-45	TW-46	TW-47	TW-48	TW-49	TW-50	TW-51	TW-52	TW-53	TW-54	TW-55	SS-1	SS-2	SS-3
	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Acetone	ND	ND	ND	ND	ND	ND	70	ND	ND	ND	ND	ND	220	ND	ND	ND
2-Butanone	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND
Benzene	ND	ND	ND	ND	ND	ND	47	ND	33	ND	ND	270	ND	940	680	62
Toluene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND
Ethylbenzene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	260	ND	ND
Xylenes	ND	ND	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	ND	270	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	8
Tetrachloroethene	ND	ND	ND	ND	ND	ND	ND	4,900*	ND	6	ND	ND	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	130	180	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-1,2-Dichloroethene	ND	ND	22	13	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	10	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methylene chloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbon disulfide	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vinyl acetate	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Methylphenol	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	6	ND	ND	ND	NA
Naphthalene	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	4	ND	110	17	NA
2-Methylnaphthalene	NA	NA	NA	NA	NA	NA	NA	ND	NA	NA	NA	ND	ND	130	14	NA
Petroleum Hydrocarbons	NA	NA	0.3	1.2	ND	ND	NA	0.15*	1.0	ND	ND	1.5	1.6	NA	NA	NA
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)

* Results reported are the average of two duplicate samples, calculated using one-half the detection limit for nondetects.

NA Not analyzed.
ND Not detected.

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LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- PREVIOUS MONITORING WELL (NO LONGER EXISTS)

[] BENZENE CONC. (ug/l)

NOTES
ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE BENZENE NOT DETECTED.

FIGURE 4-8

BENZENE ISOCONCENTRATION MAP (1991)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX



TW-08) and in the southern portion of the study area (at TW-51). The benzene plume is fairly well defined based on the 1991 data. The source of contamination in well TW-08 was a leaking UST located south of Building 1501. The UST has since been removed and the soils remediated.

The total petroleum hydrocarbons plume was much smaller in 1991 than that delineated in 1990. The current plume is shown in Figure 4-9. Petroleum hydrocarbons were detected in only 6 wells, at a maximum concentration of 1.6 mg/L. The detection limits achieved by the fixed base laboratory were on the order of 0.2 mg/L, therefore the occurrence of petroleum hydrocarbons is fairly well defined.

The maximum concentration of PCE was much greater in 1991 (4,900 $\mu\text{g/L}$) than in 1990 (290 $\mu\text{g/L}$). During both sampling events, the maxima was centered in the area of Building 1600. The area affected by PCE is relatively small and well defined, given the number of surrounding wells in which PCE was not detected. A single detection of PCE was also noted in well TW-52, which is located near the automobile repair shop in the northern portion of the study area. The isoconcentration contour map for PCE in 1991 is presented in Figure 4-10.

Figure 4-11 contains the isoconcentration map for TCE in 1991. Two of the new wells installed along the flightline (TW-46 and TW-47) were found to contain TCE (at concentrations of 130 and 180 $\mu\text{g/L}$, respectively). However, no further upgradient wells exist to serve to define the upgradient extent of TCE contamination. A single detection of TCE was also observed in well TW-15, which is located in the southern portion of the study area. No other wells were found to contain TCE. It is possible that the source of TCE in wells TW-46 and TW-47 is from the maintenance facilities that were historically located along Bill Mitchell Road.

Figure 4-12 presents isoconcentration contours for trans-1,2-dichloroethene. The concentrations were low, with a maximum detection of 13 $\mu\text{g/L}$ in well TW-46. The plume contours are not closed on the western end because no wells exist in that area. However, with the low concentrations observed, no significant concentrations would be expected. A smaller plume is centered around wells TW-45 and TW-37.

Figure 4-13 presents the positive detections for vinyl chloride. Five wells along the flightline were found to contain vinyl chloride (at concentrations ranging from 10 $\mu\text{g/L}$ to 27 $\mu\text{g/L}$). Isoconcentration contours were not generated on the map due to the wide aerial extent of the positive detections. The source(s) of vinyl chloride is unknown. Some research indicates that vinyl chloride may be a degradation product of PCE.

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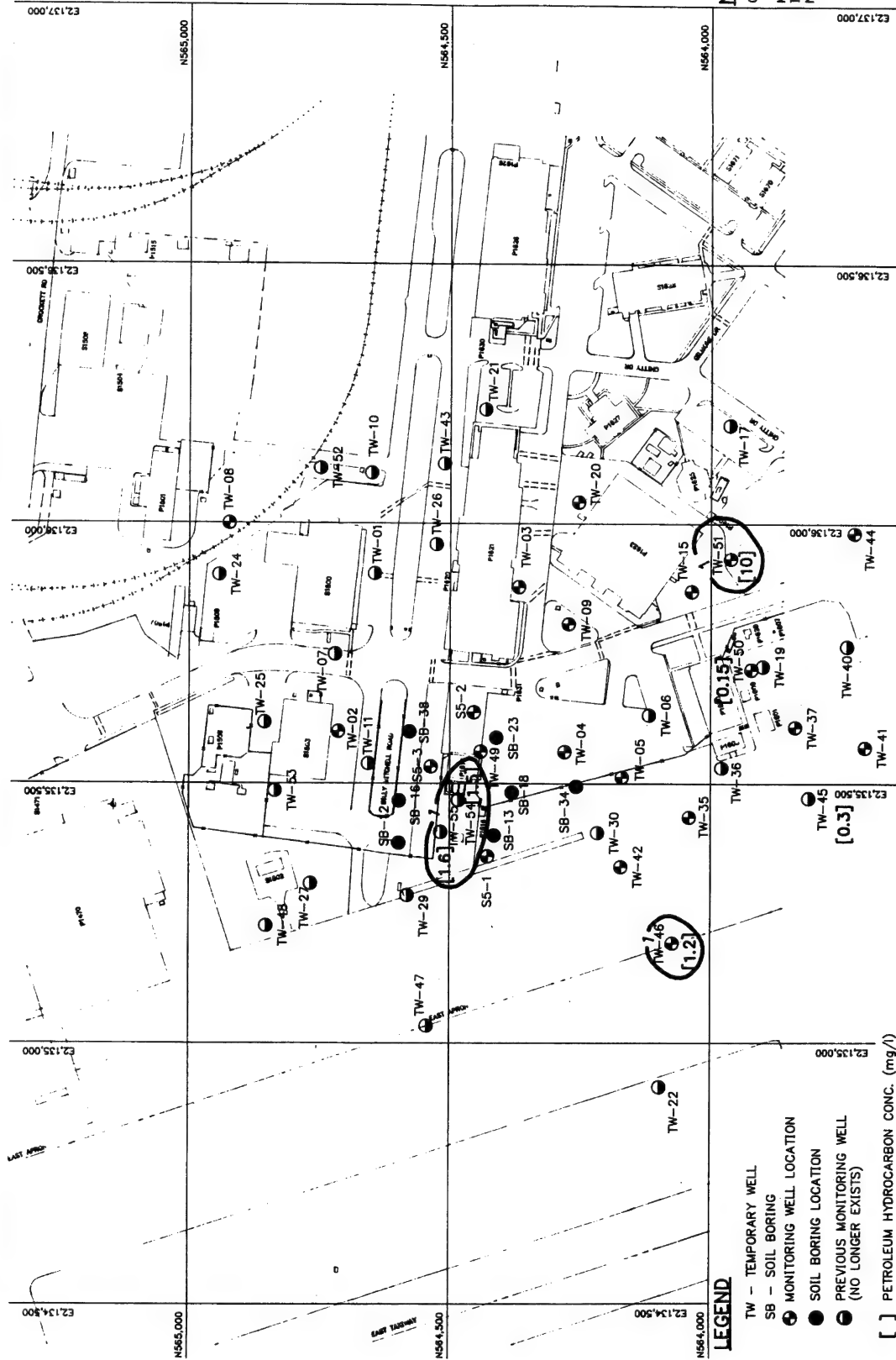


FIGURE 4-9

PETROLEUM HYDROCARBON ISOCONCENTRATION MAP (1991)

SITE S-5

KELLY AIR FORCE BASE, SAN ANTONIO, TX

0 200 400
SCALE IN FEET



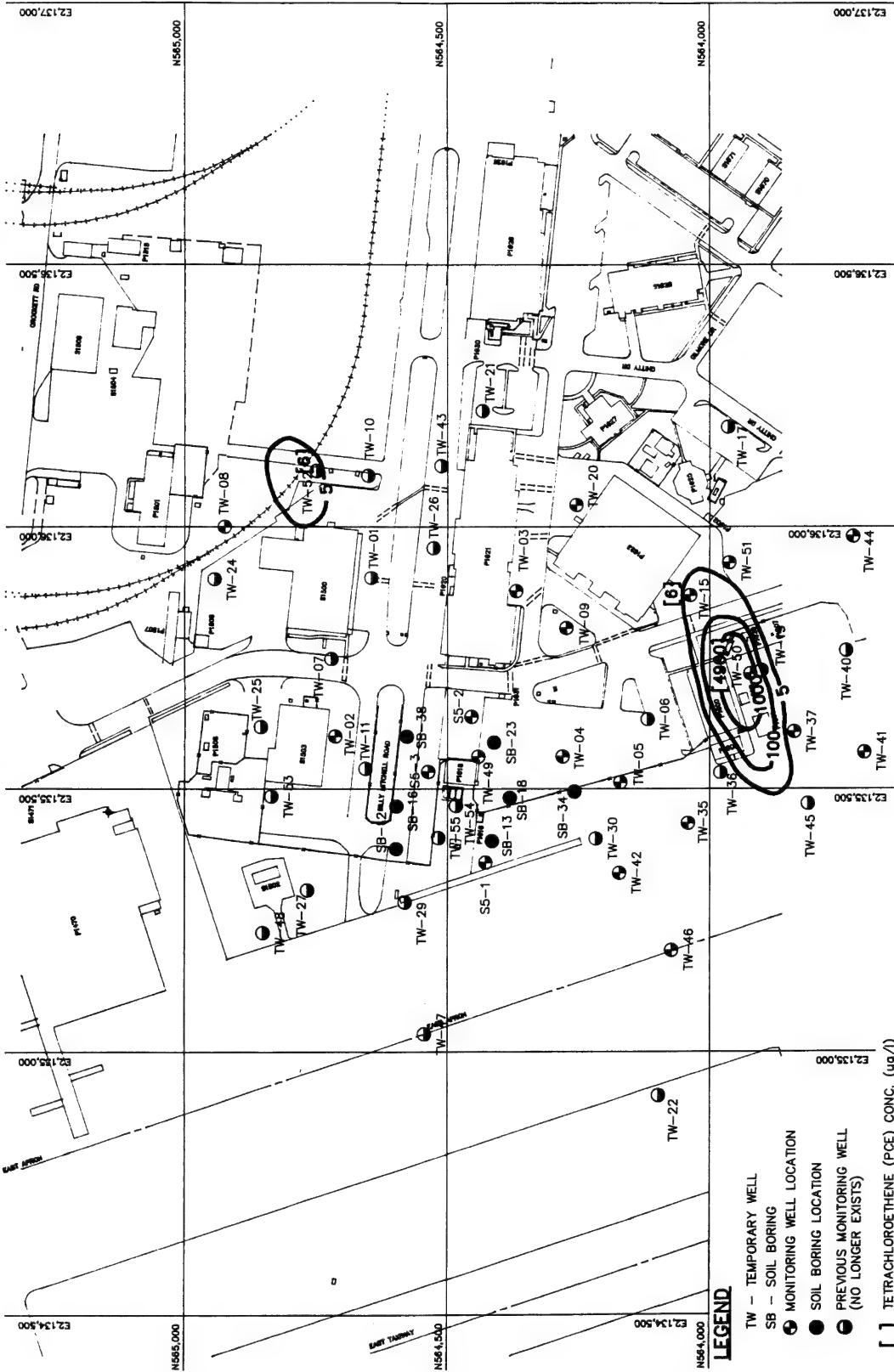
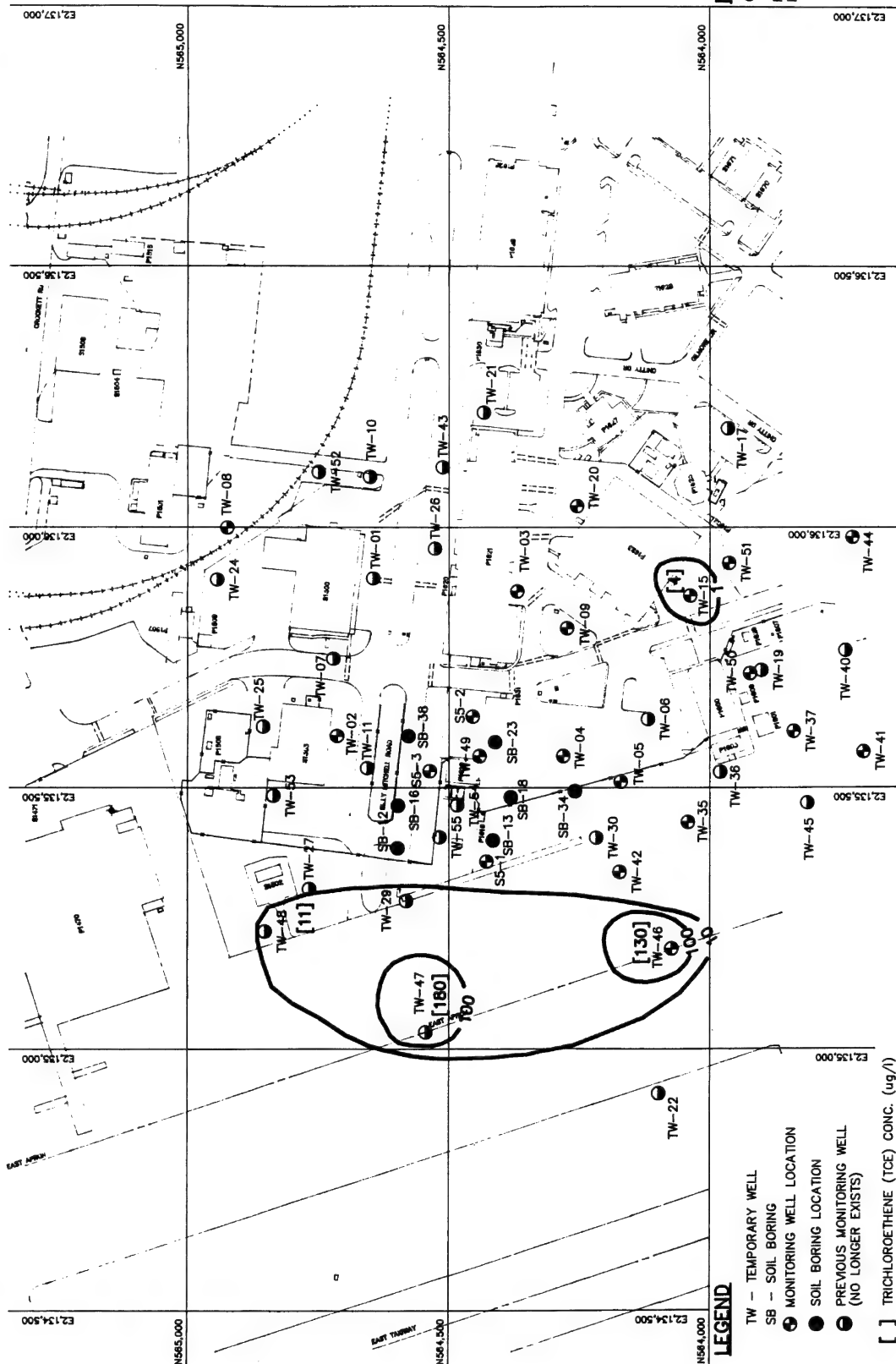


FIGURE 4-10

PCE ISOCONCENTRATION MAP (1991)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX





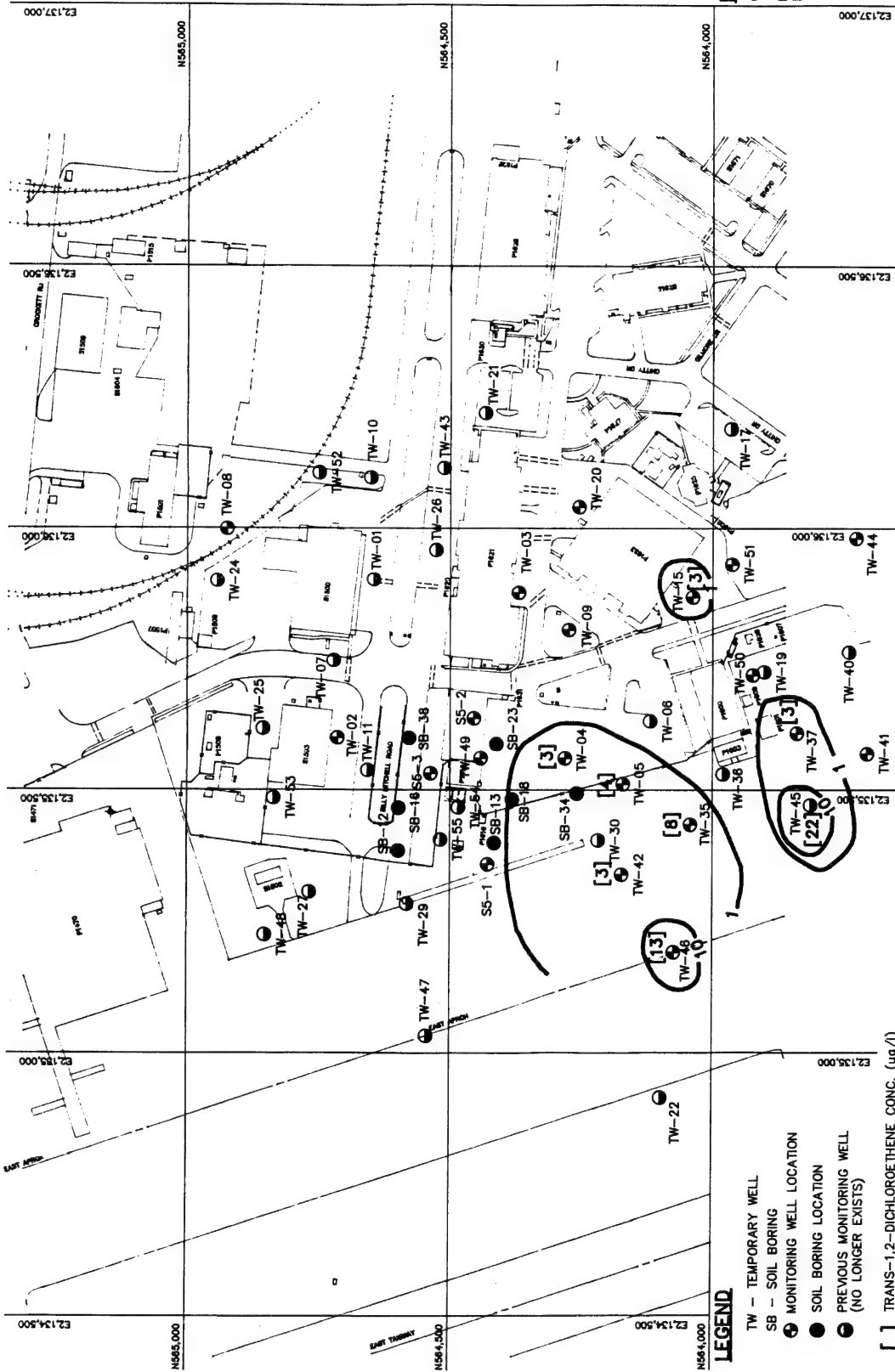
TCE ISOCONCENTRATION MAP (1991)

SITE S-5

KELLY AIR FORCE BASE, SAN ANTONIO, TX

FIGURE 4-11





LEGEND

- TW - TEMPORARY WELL
SB - SOIL BORING
● MONITORING WELL LOCATION
● SOIL BORING LOCATION
● PREVIOUS MONITORING WELL
(NO LONGER EXISTS)

[] TRANS-1,2-DICHLOROETHENE CONC. (ug/l)

NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE TRANS-1,2-DCE NOT DETECTED

TRANS-1.2-DCE ISOCONCENTRATION MAP (1991)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX

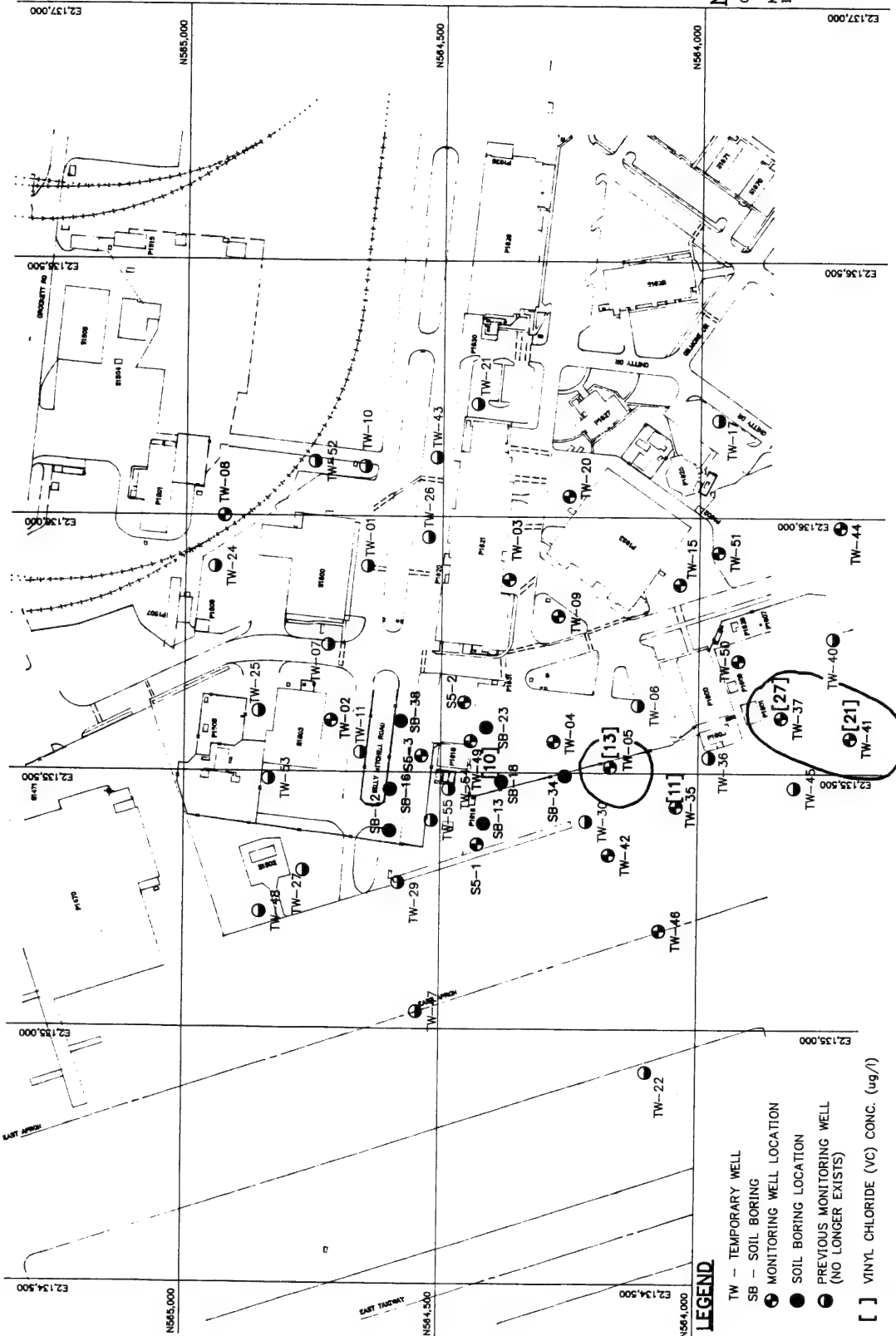
FIGURE 4-12



HALLIBURTON NUS
Environmental Corporation

4-43





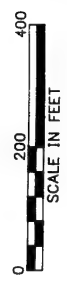
NOTES

ONLY POSITIVE DETECTIONS ARE SHOWN.
MONITORING WELLS WITH NO DATA
INDICATE VC NOT DETECTED.

FIGURE 4-13



**VC CONCENTRATION MAP (1991)
SITE S-5
KELLY AIR FORCE BASE, SAN ANTONIO, TX**



LEGEND

- TW - TEMPORARY WELL
- SB - SOIL BORING
- MONITORING WELL LOCATION
- SOIL BORING LOCATION
- PREVIOUS MONITORING WELL (NO LONGER EXISTS)
- [] VINYL CHLORIDE (VC) CONC. (ug/l)

A few semivolatile organic chemicals were detected in the seven groundwater samples in which they were analyzed. These wells were all located in the central portion of the tank farm plume and contained some of the more soluble semivolatile organic compounds. For example, 2-methylphenol was found in well TW-54 at a concentration of 6 µg/L, naphthalene was found in three wells (TW-54, S5-1, and S5-2) at concentrations ranging from 4 µg/L to 110 µg/L, and 2-methylnaphthalene was found in wells S5-1 and S5-2 at concentrations of 130 µg/L and 14 µg/L, respectively.

4.4.3 Field Measurements

Field measurements of temperature, pH, and specific conductance were made during monitoring well development and sampling. In addition, observations of turbidity were made at the same time. These data are summarized in Tables 4-8 (1990) and 4-9 (1991). Temperatures ranged from 24.1°C to 32.6°C, and the pH ranged from 6.53 to 8.33 standard units. Specific conductance ranged from 495 to 1,300 µmhos/cm. No patterns were readily apparent in these data. Because the groundwater was too turbid to allow use of the turbidity meter, only qualitative observations were made.

TABLE 4-8

FIELD MEASUREMENTS - GROUNDWATER (1990)
 SITE S-5
 KELLY AIR FORCE BASE
 SAN ANTONIO, TEXAS

Parameter	TW-01	TW-02	TW-03	TW-04	TW-05	TW-06	TW-07	TW-08	TW-09	TW-10	TW-11	TW-15	TW-17	TW-19	TW-20	TW-21
Temperature (°C)	32.0	NA	30.9	29.4	32.0	30.2	29.8	28.9	31.6	32.5	29.2	30.4	30.2	31.9	29.4	29.5
pH (Standard Units)	7.41	NA	7.45	7.04	7.35	7.29	7.33	7.44	7.23	7.37	7.00	7.41	7.32	7.70	7.22	7.36
Specific Conductance (µmho/cm)	730	NA	700	660	720	720	760	760	530	700	675	560	620	740	710	780
Turbidity ⁽¹⁾	Very Cloudy	NA	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Slightly Cloudy	Very Cloudy	Very Cloudy

Parameter	TW-24	TW-25	TW-26	TW-27	TW-29	TW-30	TW-35	TW-36	TW-37	TW-41	TW-42	TW-43	TW-44	S5-1-A	S5-2-A	S5-3-A
Temperature (°C)	29.3	29.0	32.6	29.9	29.3	30.4	31.8	32.5	32.0	32.3	32.2	29.6	30.9	26.0	30.0	29.3
pH (Standard Units)	7.34	7.48	7.42	7.54	7.16	7.50	7.28	7.40	7.22	7.64	7.41	7.65	7.52	7.98	7.04	7.21
Specific Conductance (µmho/cm)	820	740	920	800	720	700	740	800	850	660	720	720	495	600	580	720
Turbidity ⁽¹⁾	Very Cloudy	Slightly Cloudy	Cloudy	Clear	Very Cloudy	Very Cloudy	Very Cloudy	Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Cloudy	Very Cloudy	Clear	Cloudy	Slightly Cloudy

All values are final readings after well development.

NA No data available.

(1) Turbidity readings are qualitative only. The turbidity meter was unable to provide quantitative readings because of the high turbidity.

TABLE 4-9

FIELD MEASUREMENTS - GROUNDWATER (1991)

SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

Parameter	TW-01	TW-02	TW-03	TW-04	TW-06	TW-07	TW-08	TW-09	TW-15	TW-20	TW-21	TW-35	TW-37	TW-41	TW-42
Temperature (°C)	26.1	25.0	24.7	25.4	25.2	25.5	24.1	29.0	25.7	25.0	24.4	25.1	25.0	26.2	25.6
pH (Standard Units)	7.01	6.75	7.14	6.97	7.06	6.88	7.02	6.99	7.12	6.75	7.01	7.01	6.53	6.64	6.92
Specific Conductance (µmhos/cm)	840	840	850	760	820	800	860	680	850	800	1300	800	860	780	840
Turbidity(1)	Cloudy	Cloudy	Very Cloudy	Very Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy	Very Cloudy	Very Cloudy	Very Cloudy	Cloudy	Cloudy	Very Cloudy

Parameter	TW-43	TW-44	TW-45	TW-46	TW-47	TW-48	TW-49	TW-50	TW-51	TW-52	TW-53	TW-54	TW-55	S5-2	S5-3
Temperature (°C)	25.0	25.1	25.6	27.2	25.1	28.7	24.8	26.7	25.2	26.2	25.4	26.9	25.2	24.7	24.6
pH (Standard Units)	6.78	7.15	8.33	7.52	7.09	7.49	7.41	7.97	7.11	8.56	7.31	7.86	7.17	6.65	6.63
Specific Conductance (µmhos/cm)	780	600	710	440	530	680	440	660	460	640	700	430	860	760	810
Turbidity(1)	Slightly Cloudy	Very Cloudy	Cloudy	Slightly Cloudy	Slightly Cloudy	Slightly Cloudy	Slightly Cloudy	Slightly Cloudy	Opaque	Very Cloudy	Cloudy	Cloudy	Slightly Cloudy	Very Cloudy	Opaque

5.0 CONTAMINANT FATE AND TRANSPORT

5.1 INTRODUCTION

This section contains a discussion of the various chemical and physical properties of the chemicals detected at Site S-5 that determine the behavior of the chemicals in the environment. In addition, major actual or potential contaminant migration pathways are discussed.

5.2 CHEMICAL AND PHYSICAL PROPERTIES

Various chemical and physical properties of site contaminants are presented and discussed in this section. These parameters are used to estimate the environmental behavior of site-related chemicals. Physical and chemical properties of the organic contaminants at Site S-5 are shown in Table 5-1.

Empirically determined literature values of water solubility, octanol/water partition coefficients, soil/sediment adsorption coefficients, vapor pressure, Henry's Law constants, bioconcentration factors, and specific gravity are presented, when available. Calculated values, which were obtained using approximation methods, are presented when literature values are unavailable. A discussion of the environmental significance of each of these parameters follows.

5.2.1 Specific Gravity

Specific gravity is the ratio of the weight of a given volume of pure chemical at a specified temperature to the weight of the same volume of water at a given temperature. Its primary use is to determine whether a contaminant will have a tendency to float or sink in water if it is present as a pure compound or at very high concentrations. Contaminants with a specific gravity less than one will tend to float. Of the commonly detected contaminants, the ketones and some of the monocyclic aromatics have specific gravities less than one. The halogenated aliphatics, halogenated aromatics, and polynuclear aromatic hydrocarbons (PAHs) have specific gravities greater than one.

5.2.2 Vapor Pressure

Vapor pressure provides an indication of the rate at which a chemical volatilizes from both soil and water. It is of primary significance at environmental interfaces, such as soil/air or water/air. Volatilization is not as important when evaluating contaminated groundwater and subsurface soils.

TABLE 5-1

ENVIRONMENTAL FATE AND TRANSPORT PARAMETERS FOR ORGANIC CHEMICALS

SITE 5-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS

CAS Number	Chemical	Molecular Weight (1)(2)(5)	Specific Gravity (20/4°C) (1)(5)	Vapor Pressure (mm Hg @ 20°C) (1)(2)(5)(7)(9)(12)(13)	Water Solubility (mg/L @ 20°C) (1)(2)(5)(7)(9)(12)(13)	Octanol/Water Partition Coefficient (Kow) (1)(2)(5)(12)(13)	Organic Carbon Partition Coefficient (Koc) (2)(3)(8)	Henry's Law Constant (atm-m ³ /mole) (2)(4)(12)(13)	Bioconcentration Factor (µg/kg/µg/L) (2)(10)
KETONES									
67-64-1	Acetone	58.08	0.791	270 (30°C)	680,000	NA	9.2	3.43×10^{-5}	0.3
78-93-3	2-Butanone	72.1	0.805	78	353,000 (10°C)	1.95	17	2.08×10^{-5}	0.6
MONOCYCLIC AROMATICS									
71-43-2	Benzene	78.12	0.879	95.2 (25°C)	1,780	135	65	5.5×10^{-3}	7.84
108-88-3	Toluene	92.13	0.867	28.7	535	620	300	6.66×10^{-3}	25.5
100-41-4	Ethylbenzene	106.16	0.867	7	152	2,200	1,100	6.6×10^{-3}	66.8
1330-20-7	Xylenes (Total)(7)	106.16	0.870	6.5 (para)	187	1,195	248	4.33×10^{-3}	150
108-90-7	Chlorobenzene	112.56	1.107	11.7	500	690	330	3.58×10^{-3}	164
95-48-7	2-Methylphenol	108.1	1.041	0.24 (25°C)	8,700 (40°C)	89	24.5	3.92×10^{-6}	11
HALOGENATED ALIPHATICS									
71-55-6	1,1,1-Trichloroethane	133.41	1.350	123	720 (25°C)	320	152	3.0×10^{-2}	81
75-34-3	1,1-Dichloroethane	98.96	1.174	180	5,500 (25°C)	63	30	4.26×10^{-3}	19
127-18-4	Tetrachloroethane	165.83	1.626	14	200	759	364	1.53×10^{-2}	252
79-01-6	Trichloroethene	131.39	1.460	60	1,100	263	126	9.1×10^{-3}	97
156-60-5	trans-1,2-Dichloroethene	96.94	1.260	326	600	123	59	6.7×10^{-2}	48
75-35-4	1,1-Dichloroethene	96.94	1.260	591 (25°C)	400	135	65	1.9×10^{-1}	53
75-01-4	Vinyl chloride	62.5	0.912 (15/4°C)	2,660 (25°C)	2,700	17	8.2	8.14×10^{-2}	5.7
75-09-2	Methylene chloride	84.94	1.37	362	800	123	8.8	2.03×10^{-3}	6

TABLE S-1
ENVIRONMENTAL FATE AND TRANSPORT PARAMETERS FOR ORGANIC CHEMICALS
SITE S-5
KELLY AIR FORCE BASE
SAN ANTONIO, TEXAS
PAGE TWO

CAS Number	Chemical	Molecular Weight (1)(2)(5)	Specific Gravity (20/4°C) (1)(5)	Vapor Pressure (mm Hg @ 20°C) (1)(2)(5)(7)(9)(12)(13)	Water Solubility (mg/L @ 20°C) (1)(2)(5)(7)(9)(12)(13)	Octanol/Water Partition Coefficient (K _{ow}) (1)(2)(5)(12)(13)	Organic Carbon Partition Coefficient (K _{oc}) (2)(3)(8)	Henry's Law Constant (atm-m ³ /mole) (2)(4)(12)(13)	Bioconcentration Factor (µg/Kg/µg/L) (2)(10)
POLYNUCLEAR AROMATIC HYDROCARBONS									
91-20-3	Naphthalene	128.2	1.152	8.7 x 10 ⁻³ (25°C)	31.7 (25°C)	1,950	940	4.6 x 10 ⁻⁴	420
91-57-6	2-Methylnaphthalene	142.19	1.025	1 (53°C) (12)	27 (25°C)	0.46	2.2/3.82	3.5 x 10 ⁻⁴	1.6
MISCELLANEOUS ORGANICS									
75-10-0	Carbon disulfide	76.14	1.263	260	2,300 (22°C)	100	142	1.13 x 10 ⁻²	11
108-05-4	Vinyl acetate	86.1	0.932	83	25,000	NA	NA	3.76 x 10 ⁻⁴	NA

NA Not available.

- (1) Verschuere, 1983.
 (2) U.S. EPA, December 1982.
 (3) Lyman et al. 1990, equations 4-10 and 4-8, respectively.
 (4) Lyman et al. 1990, equation 15-8.
 (5) U.S. EPA, December 1979.
 (6) Average of o-, m-, and p-xylene.
 (7) Lyman et al. 1990, equation 2-6.
 (8) Lyman et al. 1990, equations 4-5 and 4-8, average value.
 (9) Lyman et al. 1990, equation 2-2.
 (10) Lyman et al. 1990, equation 5-2.
 (11) No data available; data for similar compound 1-methylnaphthalene.
 (12) Howard, 1990.
 (13) Howard, 1989.

Vapor pressures for ketones, monocyclic aromatics, and halogenated aliphatics are generally higher than vapor pressures for polynuclear aromatic hydrocarbons. Chemicals with higher vapor pressures are expected to enter the atmosphere more readily than chemicals with lower vapor pressures. Volatilization is a significant loss process for volatile organics in surface waters or surface soils. Volatilization is not significant for metals.

No surface soil samples (0.5 to 2.5 feet deep) were analyzed by the fixed base laboratory. However, no high concentrations of volatile organics were found by the field laboratory. Where chemicals may have been spilled, the hot climate of the San Antonio area would be expected to cause rapid volatilization of chemicals. The releases of the fuel-related constituents occurred from underground tanks and piping, and therefore volatilization would not be significant for the soils affected by these chemicals.

5.2.3 Solubility

The rate at which a chemical is leached from a waste deposit by infiltrating precipitation is in part proportional to its water solubility. More soluble chemicals are more readily leached than less soluble chemicals. The water solubilities presented in Table 5-1 indicate that all of the chemicals listed are fairly soluble. Less soluble chemicals such as PCBs, pesticides, and many polynuclear aromatic hydrocarbons (PAHs) were not detected at the site. The groundwater data also show that the volatile organics are the most prevalent groundwater contaminants.

On the other hand, the solubility of inorganics is much less straightforward and is strongly influenced by valence state and form (e.g., hydroxide, oxide, carbonate, etc.). Solubility also depends on pH, Eh, and the other ionic species in solution. Lead was the only metal analyzed for at this site, and it was found only at a maximum concentration of 20 µg/L, which is greater than the current Safe Drinking Water Act action level (15 µg/L).

5.2.4 Octanol/Water Partition Coefficient

The octanol/water partition coefficient is a measure of the equilibrium partitioning of chemicals between octanol and water. A linear relationship between the octanol/water partition coefficient and the uptake of chemicals by fatty tissues of animal and human receptors (the bioconcentration factor) has been determined (Lyman et al., 1990). It is also useful in characterizing the sorption of compounds by organic soils where experimental values are not available. All of the chemical found at the site are expected to partition to some extent, however other chemicals such as PAHs or PCBs are

much more likely to do so. The octanol/water partition coefficient is also used to estimate bioconcentration factors in aquatic organisms.

5.2.5 Soil/Sediment Adsorption Coefficient

The soil/sediment adsorption coefficient (also known as the organic carbon partition coefficient) indicates the tendency of a chemical to bind to soil particles containing organic carbon. Chemicals with high soil/sediment coefficients generally have low water solubilities and vice versa. This parameter may be used to infer the relative rates at which the more mobile chemicals such as ketones, monocyclic aromatics, and halogenated aliphatics are transported in the groundwater. Other chemicals such as the PAHs and PCBs, which were not detected at this site, are relatively immobile in the environment and are preferentially bound to the soil. These compounds are not subject to groundwater transport to the extent that compounds with higher solubilities are.

5.2.6 Henry's Law Constant

Both the vapor pressure and the water solubility are of use in determining volatilization rates from surface water bodies and from groundwater. The ratio of these two parameters (the Henry's Law constant) is used to calculate the equilibrium contaminant concentrations in the vapor (air) versus the liquid (water) phases for the dilute solutions commonly encountered in environmental settings. In general, chemicals having a Henry's Law constant of greater than 5×10^{-6} atm-m³/mole such as those found at the site would be expected to be found in the atmosphere or in the soil gas.

5.2.7 Bioconcentration Factor

Bioconcentration factors (BCFs) represent the ratio of aquatic animal tissue concentration to concentration of a chemical. The ratio is both contaminant- and species-specific. When site-specific values are not measured, literature values are used or the BCF is derived from the octanol/water partition coefficient. The organic chemicals found at Site S-5 all have relatively low BCFs in comparison to such chemicals as PAHs or PCBs, which were not detected at this site.

5.2.8 Summary

Volatile organic chemicals, such as the monocyclic aromatics and the halogenated aliphatics, are the contaminants found most often in the groundwater at the site. These classes of chemicals have high solubilities and low soil/sediment coefficients, and are most prevalent in the samples collected from

the alluvial aquifer. These chemicals are also frequently found in subsurface soils at or near the water table.

The distribution of organic chemicals in the environmental media sampled during the field investigation is governed primarily by these physical and chemical properties. However, human intervention may also play a role in contaminant migration such as during construction if proper erosion control measures are not applied.

5.3 CONTAMINANT PERSISTENCE

The persistence of various classes of site contaminants is discussed in this section. Several transformation mechanisms affect contaminant persistence, such as hydrolysis, biodegradation, photolysis, and oxidation/reduction reactions. The following general classes of chemicals are discussed:

- Monocyclic aromatics
- Halogenated aliphatics
- Phenols
- Polynuclear aromatic hydrocarbons (PAHs)

5.3.1 Monocyclic Aromatics

Monocyclic aromatic hydrocarbons such as benzene, toluene, and ethylbenzene are not considered to be persistent environmental contaminants. Such compounds are subject to degradation via the action of both soil and aquatic microorganisms. The biodegradation of these compounds in the soil matrix is dependent on the abundance of microflora, macronutrient availability, soil reaction (pH), temperature, etc.

Although these compounds are amenable to microbial degradation, the rate of degradation cannot be estimated because macronutrient availability is unknown. If these chemicals discharge to a surface water body, volatilization and biodegradation may occur relatively rapidly. For example, a reported first-order biodegradation constant for benzene is 0.11 day^{-1} in aquatic systems (Lyman et al., 1990). This corresponds to an aquatic half-life of approximately 6 days. Other monocyclic aromatics are subject to similar degradation processes in aquatic environments (U.S. EPA, December 1982). However, chlorinated monocyclic aromatics such as chlorobenzene are not expected to be as susceptible to microbial degradation. For example, a first-order biodegradation constant for

chlorobenzene is 0.0045 day^{-1} in aquatic systems (Lyman et al., 1990). This corresponds to a half-life of approximately 150 days.

Additional environmental degradation processes, such as hydrolysis and photolysis, are considered to be insignificant fate mechanisms for monocyclic aromatics (U.S. EPA, December 1982). However, some monocyclic aromatic compounds such as benzene and toluene have been shown to undergo clay-, mineral-, and soil-catalyzed oxidation (Dragun, 1988).

5.3.2 Halogenated Aliphatics

Chlorinated aliphatic hydrocarbons such as trichloroethene (TCE) and tetrachloroethene (PCE) are subject to reductive dehalogenation via the action of anaerobic bacteria. Research indicates that degradation of highly chlorinated ethanes is a relatively slow process. While PCE and TCE are reportedly susceptible to substantial degradation, the primary end product is reportedly vinyl chloride, which degrades very slowly (Cline and Viste, 1984). It does not appear that appreciable degradation of halogenated aliphatics occurs in aerobic aquatic systems (U.S. EPA, December 1982) or in unsaturated soils (Lyman et al., 1990). Photolysis is not considered to be a relevant degradation mechanism for this class of compounds (U.S. EPA, December 1982). Limited hydrolysis of saturated aliphatics (i.e., alkanes) may occur, but it does not appear to be a significant degradation mechanism for unsaturated species (i.e., alkenes) (U.S. EPA, December 1982).

5.3.3 Phenols

Nonhalogenated phenolic compounds are relatively susceptible to biodegradation in unsaturated soils and surface waters. The presence of phenols (one detection in groundwater) is relatively uncommon at the site in comparison to volatile organics. This may be a result of either their limited use, their high solubilities, and/or their susceptibility to microbial degradation. A reported first-order biodegradation rate constant for phenol is 0.079 day^{-1} in aquatic systems (Lyman et al., 1990). This corresponds to a half-life of approximately nine days. It does not appear that hydrolysis and photolysis are significant degradation mechanisms for phenolic substances (U.S. EPA, December 1982).

5.3.4 Polynuclear Aromatic Hydrocarbons

PAHs are common constituents of oils and greases. Landspreading applications have indicated that PAHs are amenable to microbial degradation. Studies have demonstrated that PAHs are much more amenable to degradation in soil matrices than in aquatic environments (U.S. EPA, December 1979).

Under existing site conditions, with PAHs found only in the groundwater and not in the surface soil, biodegradation may not be significant. PAHs do not contain functional groups that are susceptible to hydrolytic actions, and hydrolysis is considered to be an insignificant degradation mechanism. Photolysis may be a major degradation mechanism in aquatic environments but is probably insignificant in soils.

5.4 CONTAMINANT MIGRATION ROUTES

This section identifies potential contaminant release mechanisms and migration routes for Site S-5. These mechanisms were identified through an evaluation of the chemical analytical data base and the known study area characteristics.

The primary migration route currently acting at the site is the migration of soluble contaminants in groundwater. These contaminants may have entered the groundwater either directly (e.g., a subsurface release from a tank located directly above the water table) or indirectly via the leaching of contaminants from surface or shallow subsurface soil. Once in the groundwater, the contaminants migrate downgradient with the groundwater at a slower rate that is determined primarily by the soil/sediment adsorption coefficient and the amount of organic carbon in the soil. Volatile organics and soluble semivolatile organics are most susceptible to this migration route, while lead is not generally as mobile.

When the water table fluctuates in response to pumping or seasonal changes in recharge, organic chemicals may be retained in the soil when the water table lowers. These chemicals may move partially into solution again when the water table rises. This mechanism explains the high concentrations of volatile organics found in the soil samples collected from the zone near the water table.

Another potential migration route identified at the site is the potential wind erosion and entrainment of fine-grained surficial materials followed by offsite transport and deposition. No surface soil samples were collected for this investigation, therefore the potential magnitude of this process cannot be estimated except by using samples collected from a depth of 0 to 25 feet. However, exposure of subsurface soil during construction could provide contaminated source material for wind erosion.

Because the site is relatively flat, the erosion of contaminated soil by surface water runoff is felt to be insignificant at this site. Much of the study area is either paved or vegetated.

At various points along each migration pathway, the contaminants may result in exposure of local residents and/or base personnel. This aspect of contaminant migration will be discussed in more detail in Section 6.4.

5.5 FATE AND TRANSPORT MODEL

A computer model (Development and Application of a Spreadsheet-Based Multimedia Contaminant Fate and Transport Model; Jyh-Dong Chiou and Robert J. Hubbard) was utilized to perform contaminant fate and transport simulation for chemicals found in the S-5 area. The objective of this modeling task was to provide conservative estimates of contaminant concentrations at locations where human exposure to the contaminated groundwater is possible. These estimates were used in the risk assessment to determine whether migration of the residual contamination from the S-5 area can pose a threat to human health. If so, the model can then be used to determine the degree of remedial action required. The two points of exposure defined in this task are Building 1680 and the base boundary. Details of this modeling effort are included in the Draft Feasibility Study, Site S-5, HALLIBURTON NUS, June 1992.

The hydrogeological data and measured chemical concentrations were obtained during the RI Investigation. In addition to this information, the following assumptions were made in the model:

- There is not additional loading of contaminants from either the tank farm itself or the upgradient area other than the chemicals already found in the unsaturated and saturated zones in the vicinity of the tank farm.
- The sprinkler system around Building 1680 which is pumping water from the shallow saturated zone does not affect the groundwater flow significantly.
- The groundwater flow direction is directly toward the points of exposure.
- The surface infiltration from precipitation outside the source area that can dilute the downgradient contaminant plume is not considered.
- The downgradient area is initially clean of contamination.
- The fraction of organic carbon (FOC) in both the unsaturated and saturated zones is about 0.1 percent.

The first step of this modeling task was to estimate the surface infiltration rate due to precipitation that can percolate through the unsaturated zone and reach the water table. The Hydrologic Evaluation of Landfill Performance (HELP) Model was utilized to determine the rate of infiltration through a representative geologic cross-section at the source area. Only 10 percent of the calculated infiltration rate was used in the contaminant fate and transport model due to the fact that 90 percent of the surface area at Site S-5 is covered by asphalt or buildings. Results of the HELP model were also used to estimate the level of saturation in the unsaturated zone which is a required input parameter in the fate and transport model.

In the second step, contaminants associated with the tank farm and their maximum and average concentrations were identified for simulation. These contaminants include Benzene, Toluene, Ethylbenzene, Xylene, Acetone, 2-Butanone, Chloroform, 1,2/1,4-Dichlorobenzene, Naphthalene, PCE, and Vinyl Chloride. These chemicals have been found in either soil or groundwater samples taken from the S-5 tank farm area.

The third step was to use the maximum soil concentrations of the identified contaminants in unsaturated and saturated zones as the initial conditions for the worst case simulations. In the simulation, the entire unsaturated and saturated zones were assumed to be contaminated with the maximum concentrations in each zone, respectively. The size of the Benzene plume (800' x 500') was used as the maximum extent of contamination for all the chemicals except PCE which has a 200' x 200' plume. In these simulations, no degradation was assumed. Results of these worst case simulations are summarized in Table 5-2. Table 5-2 shows the predicted maximum concentrations at the points of exposure and the times when these maximum concentrations occur. Because of all the assumptions made in the model, these predictions are very conservative (i.e. the concentrations at points of exposure are overestimated).

The Maximum Allowable Exposure Concentrations (MAEC) in Table 5-2 were set assuming the groundwater as a source of drinking water. This actually is not the case at Building 1680 where groundwater is only used for irrigation. Therefore, the predicted maximum concentrations were used in the risk assessment under a more realistic exposure scenario to determine the risk associated with the groundwater use at this location.

Although the shallow groundwater at the base boundary directly downgradient from the S-5 area is not currently used as a source of drinking water, the MAECs were used to determine the need of source remediation. As shown in Table 5-2, the only contaminant that exceeds its MAEC in the initial simulation is Benzene. When the maximum soil concentration in the saturated zone (15 ppb) was replaced by the average concentration (12 ppb), the maximum groundwater concentration at the

TABLE 5-2

Predicted Maximum Concentration at Exposure Points

CHEMICAL	MAEC (UG/L)	CURRENT MAX. CONCENTRATION AT SOURCE AREA		SIMULATED MAXIMUM GROUNDWATER CONC.		
		SOIL (UG/KG) UNSAT.	WATER (UG/L) SAT.	AT BUILDING 1680 TIME (YEARS) CONC. (UG/L)	AT BASE BOUNDARY TIME (YEARS) CONC. (UG/L)	
BENZENE	5.0	13	15	34	34.76	90
TOLUENE	1000.0	4600	930	86	637.70	250
ETHYLBENZENE	700.0	650	100	250	21.63	725
XYLENE	10000.0	[70]	[70]	62	40.86	160
ACETONE	3465.0	1040	191	34	4648.00	95
2-BUTANONE	1732.5	[20]	20	28	184.40	72
CHLOROFORM	100.0	8	[8]	32	28.02	82
1,2/1,4-DICHLOROBENZENE	75.0	[20]	20	270	1.67	700
NAPHTHALENE	138.6	[150]	[150]	160	22.57	410
TETRACHLOROETHENE *	5.0	120	240	64	13.76	190
VINYL CHLORIDE	2.0	[.0001]	[.0001]	26	2.10	70
NOTES:	MAEC - MAXIMUM ALLOWABLE EXPOSURE CONCENTRATION [] - ESTIMATED CONCENTRATION ND - NONDETECTED UNSAT. - UNSATURATED ZONE SAT. - SATURATED ZONE * - BASED ON A 200' BY 200' SOURCE AREA WHILE ALL THE OTHER CONTAMINANTS ARE BASED ON AN 800' BY 500' SOURCE AREA					

base boundary became 4.8 ppb which is less than the MAEC (5 ppb). Detailed results and computations of this simulation are included in the Draft Feasibility Study report.

6.0 BASELINE RISK ASSESSMENT

6.1 INTRODUCTION

This section provides an overview of the risk assessment methodologies employed for Site S-5 at Kelly Air Force Base. The objectives of the risk assessment are to define the actual or potential risks to human health or the environment from the presence of hazardous materials in the soil and/or groundwater and to provide the basis for risk-based cleanup criteria to be developed in the Feasibility Study.

To assess public health risks, three major aspects of chemical contamination and environmental fate and transport must be considered: (1) contaminants with toxic characteristics must be found in environmental media and must be released by either natural processes or human action; (2) pathways by which actual or potential exposure occurs must be present; and (3) human or environmental receptors must be present to complete the exposure route. Risk is a function of both toxicity and exposure; without any one of the factors listed above, there will be no risk.

The risk assessment estimates the potential for human health risk at the site. Information on the distribution of contamination, the toxicity of the compounds detected in the various media, and a site-specific estimate of chemical intake via assumed exposure routes will be combined to estimate potential risks. This section provides a summary of the process used, which is in accordance with the latest EPA guidance (U.S. EPA, December 1989). Although this process is somewhat different from that described in the current Brooks RI/FS guidance (Brooks AFB, March 1991), it meets the requirements of the Statement of Work, as well as is consistent with previous reports prepared for Kelly AFB.

A risk assessment contains four general sections: (1) Data Evaluation; (2) Toxicity Assessment; (3) Exposure Assessment; and (4) Risk Characterization. Each of these components is described below.

The Data Evaluation (Section 6.2) is primarily concerned with the selection of chemicals of concern that are representative of the type and magnitude of potential human health and/or environmental effects. Contaminant concentrations relative to background levels, contaminant release and environmental transport mechanisms, exposure routes, and toxicity are considered to develop a list of contaminants used to define the site-associated risks.

The Toxicity Assessment (Section 6.3) presents available human health and environmental criteria for all the chemicals of concern. Quantitative toxicity indices are presented where they are available, including any applicable regulatory standards and criteria. Enforceable standards such as Maximum Contaminant Levels (MCLs), regulatory guidelines such as Ambient Water Quality Criteria (AWQC) and Health Advisories, and dose-response parameters such as Reference Doses (RfDs) and Cancer Slope Factors (CSFs) are presented for each chemical of concern.

The Exposure Assessment (Section 6.4) identifies potential human or environmental exposures either at the source area or off site. Exposure routes are developed from information on the source area contaminant concentrations, contaminant release mechanisms, patterns of human activity, and other pertinent information. Section 6.4 presents all the equations and relevant input parameters for calculating human intakes.

The Risk Characterization (Section 6.5) compares the predicted intakes to relevant regulatory standards or guidelines to define risks associated with threshold (noncarcinogenic) and nonthreshold (carcinogenic) effects of the chemicals of concern.

6.2 DATA EVALUATION

Data evaluation uses a variety of information to select a list of chemicals of concern for each medium. The rationale for the selection of chemicals of concern follows.

6.2.1 Chemicals of Concern - Surface Soil (0.5 to 2.5 Feet)

Only two soil samples were collected for analysis from depths of less than five feet. These two samples (SB-54-0.5 and SB-55-0.5) will be used to characterize surface soils for the risk assessment. Both were analyzed only in the field laboratory for target volatile organic chemicals.

Two noncarcinogenic chemicals were detected in these samples (toluene and ethylbenzene). Therefore, both are retained as chemicals of concern. No carcinogenic chemicals were detected.

Table 6-1 presents both the list of chemicals of concern for this medium and the calculated representative concentrations (see Section 6.2.4).

TABLE 6-1
CHEMICALS OF CONCERN - SURFACE SOIL (0.5 TO 2.5 FEET)⁽¹⁾
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Known or Potential Carcinogens	Representative Concentration ⁽²⁾ (µg/kg)	Noncarcinogens	Representative Concentration ⁽²⁾ (µg/kg)
None		Toluene	340
		Ethylbenzene	640

(1) Includes sample numbers SB-54-0.5 and SB-55-0.5.

(2) Calculated as shown in Section 6.2.4.

6.2.2 Chemicals of Concern - Subsurface Soil (0.5 to 11 Feet)

Twenty-two soil samples were collected from ten different borings from depths between 0.5 and 11 feet. All soil samples from these depths are included to evaluate exposure scenarios that involve soil disturbance (i.e., mixing of surface and subsurface soils). Volatile organics analyses of these samples was performed by the field laboratory and inorganics analyses were performed in the fixed base laboratory. Deeper samples were not evaluated for human exposure because a depth of 10 to 12 feet is generally considered to be a typical depth for construction projects.

These samples contained four volatile organic chemicals, all of which were retained as chemicals of concern, as follows:

- Benzene
- Toluene
- Ethylbenzene
- Tetrachloroethene

In addition, lead was detected by the fixed base laboratory at concentrations greater than that reported as the base background concentration in earlier investigations at Kelly AFB (HALLIBURTON NUS, July 1991). Reported base background concentrations of lead are 6 mg/kg in the alluvial aquifer and 13 mg/kg in the Navarro clay.

The chemicals of concern and the calculated representative concentrations are shown in Table 6-2.

6.2.3 Chemicals of Concern - Groundwater

A number of organic chemicals were detected in the 1991 groundwater samples that were analyzed in the fixed base laboratory. The fixed base data were subjected to a more rigorous QA/QC and are therefore considered to be more representative of actual site conditions.

All detected volatile organics were retained as chemicals of concern, as follows:

- Acetone
- 2-Butanone
- Benzene
- Toluene
- Ethylbenzene

TABLE 6-2

CHEMICALS OF CONCERN - SUBSURFACE SOIL (0.5 TO 11.0 FEET)⁽¹⁾

SITE S-5

KELLY AFB

SAN ANTONIO, TEXAS

Known or Potential Carcinogens	Representative Concentration ⁽²⁾ (µg/kg)	Noncarcinogens	Representative Concentration ⁽²⁾ (µg/kg)
Benzene	27	Toluene	85
Tetrachloroethene*	36	Ethylbenzene	140
		Lead	8,000

*Chemical also exhibits noncarcinogenic health effects.

- (1) Includes sample numbers SB-06-4.5, SB-06-9.5, SB-12-4.5, SB-12-9.5, SB-13-4.5, SB-13-9.5, SB-16-4.5, SB-16-9.5, SB-18-4.5, SB-18-9.5, SB-23-4.5, SB-23-9.5, SB-34-4.5, SB-34-9.5, SB-38-4.5, SB-38-9.5, SB-54-0.5, SB-54-4.0, SB-54-9.0, SB-55-0.5, SB-55-4.0, and SB-55-9.0.
- (2) Calculated as shown in Section 6.2.4.

- Xylenes
- Chlorobenzene
- Tetrachloroethene
- Trichloroethene
- trans-1,2-Dichloroethene
- 1,1-Dichloroethene
- Vinyl chloride
- 1,1,1-Trichloroethane
- 1,1-Dichloroethane
- Methylene chloride
- Vinyl acetate
- Carbon disulfide

In addition, three semivolatile organic chemicals were detected in the groundwater samples. Two of these, naphthalene and 2-methylphenol, were retained as chemicals of concern. The third semivolatile, 2-methylnaphthalene, was found at similar concentrations as naphthalene and therefore is considered to be adequately represented by naphthalene.

Lead was analyzed only during 1990 in the field laboratory. Lead will also be considered in the risk assessment because some concentrations exceeded the recently finalized lead action level in drinking water (U.S. EPA, June 7, 1991).

The final list of groundwater chemicals of concern is presented in Table 6-3, along with the calculated representative concentrations that were used in the risk assessment.

6.2.4 Representative Concentrations

The risk assessment for this site was performed using a representative concentration for each chemical of concern in each medium. The representative concentration was calculated using the latest risk assessment guidance from the EPA (U.S. EPA, December 1989).

The calculation of the representative concentration is a two-step process. First, the standard deviation of the sample set must be determined as follows:

TABLE 6-3
CHEMICALS OF CONCERN - GROUNDWATER⁽¹⁾
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Known or Potential Carcinogens	Representative Concentration ⁽²⁾ (µg/L)	Noncarcinogens	Representative Concentration ⁽²⁾ (µg/L)
Benzene	185	Acetone	35
Tetrachloroethene*	580	2-Butanone	3
Trichloroethene	30	Toluene	15
1,1-Dichloroethene*	64	Ethylbenzene	260
Vinyl chloride	7	Xylenes	33
Methylene chloride	1	Chlorobenzene	2
		1,1,1-Trichloroethane	73
		1,1-Dichloroethane	33
		1,2-Dichloroethene	5
		Vinyl Acetate	6
		Naphthalene	57
		2-Methylphenol	6
		Carbon disulfide	6
		Lead	5

*Chemical also exhibits noncarcinogenic health effects.

- (1) Includes sample numbers TW-03, TW-04, TW-05, TW-06, TW-07, TW-08, TW-09, TW-15, TW-20, TW-35, TW-37, TW-41, TW-42, TW-45, TW-46, TW-47, TW-48, TW-49, TW-50, TW-51, TW-52, TW-54, TW-55, S5-1, S5-2, S5-3. Duplicate sample results were averaged and counted as one sample.
- (2) Calculated as shown in Section 6.2.4

$$S = \left[\frac{\sum X_i^2 - \frac{(\sum X_i)^2}{n}}{n-1} \right]^{1/2}$$

where: S = standard deviation
 X_i = individual sample value
 n = number of samples

The upper 95 percent confidence limit (UCL) is then calculated as follows:

$$UCL = \bar{X} + t \left[\frac{S}{n^{1/2}} \right]$$

where: \bar{X} = arithmetic average value for the sample set
 t = two-sided t distribution factor, based on degrees of freedom (n-1)
 S = standard deviation
 n = number of samples
 UCL = representative concentration

For the UCL, $t = t_{0.975}$

For small sample sets or sample sets with results less than one-half the detection limit, the UCL can exceed the maximum detected concentration. In these cases, the maximum concentration was selected as the representative concentration. A sample calculation is provide in Appendix E.

6.3 TOXICITY ASSESSMENT

The purpose of this section is to identify the potential health hazards associated with exposure to each of the chemicals of concern. A toxicological evaluation characterizes the inherent toxicity of a compound. The literature indicates that many of the chemicals of concern detected at Site S-5 cause carcinogenic and/or noncarcinogenic health effects in humans. In addition, many of the chemicals have adverse effects on environmental receptors. Although the chemicals of concern may cause adverse health effects, dose-response relationships and the potential for exposure must be evaluated before the risks to receptors can be determined. Dose-response relationships correlate the magnitude of the intake with the probability of toxic effects, as discussed below.

6.3.1 Health Effects

An important component of the risk assessment process is the relationship between the intake of a chemical (the amount of a chemical that is absorbed by a receptor) and the potential for adverse health effects resulting from that intake. Dose-response relationships provide a means by which potential public health impacts may be quantified. The published information on doses and responses is used in conjunction with information on the nature and magnitude of human exposure to develop an estimate of potential health risks.

Standard Reference Doses (RfDs) and/or Cancer Slope Factors (CSFs) have been developed by the EPA for many organics and inorganics. This section provides a brief description of these parameters.

6.3.1.1 Reference Dose (RfD)

The RfD is developed by the EPA for chronic and/or subchronic human exposure to hazardous chemicals and is solely based on the noncarcinogenic health effects imparted by a chemical. The RfD is usually expressed as a dose (mg) per unit body weight (kg) per unit time (day). It is generally derived by dividing a no-observed-(adverse)-effect-level (NOEL or NOAEL) or a lowest-observed-(adverse)-effect-level (LOAEL) by an appropriate uncertainty factor. NOAELs, etc., are determined from laboratory or epidemiological toxicity studies. The uncertainty factor is based on the availability of toxicity data.

Uncertainty factors are generally applied as multiples of ten to represent specific areas of uncertainty in the available data. A factor of ten is used to account for variations in the general population (to protect sensitive subpopulations), when extrapolating test results from animals to humans (to account for interspecies variability), when a NOAEL derived from a subchronic study (instead of a chronic study) is used to develop the RfD, and when a LOAEL is used instead of a NOAEL. In addition, EPA reserves the use of a modifying factor of up to ten for professional judgment of uncertainties in the data base not already accounted for. The default value of the modifying factor is 1.

The RfD incorporates the surety of the evidence for chronic human health effects. Even if applicable human data exist, the RfD (as diminished by the uncertainty factor) still maintains a margin of safety so that chronic human health effects are not underestimated. Thus, the RfD is an acceptable guideline for evaluation of noncarcinogenic risk, although the associated uncertainties preclude its use for precise risk quantitation.

6.3.1.2 Cancer Slope Factor (CSF)

CSFs are applicable for estimating the lifetime probability (assuming a 70-year lifetime) of human receptors developing cancer as a result of exposure to known or suspected carcinogens. This factor is generally reported by the EPA in units of (mg/kg/day)⁻¹ and is derived through an assumed low-dosage linear relationship and an extrapolation from high to low dose responses determined from animal studies. The value used in reporting the CSF is the upper 95 percent confidence limit.

6.3.1.3 Weight-Of-Evidence

The weight-of-evidence designations indicate the likelihood that a chemical is a human carcinogen, based on both animal and human studies. The classification is as follows:

- A Known human carcinogen
- B1 Indicates that limited human data are available.
- B2 Indicates that there is sufficient evidence of carcinogenicity in animals, but inadequate or no evidence in humans.
- C Possible human carcinogen
- D Not classifiable as to human carcinogenicity
- E Evidence of noncarcinogenicity in humans

6.3.2 Applicable or Relevant and Appropriate Requirements (ARARs)

This section presents available regulatory standards or guidelines for all of the chemicals of concern at Site S-5. Currently, the only enforceable Federal regulatory standards for exposures to groundwater contamination are the MCLs. However, MCLs have not been specified for several of the chemicals of concern; therefore, other regulatory guidelines may be used for comparative purposes to infer health risks and environmental impacts. Relevant regulatory guidelines include the AWQC, Maximum Contaminant Level Goals (MCLGs), and Health Advisories.

6.3.2.1 Maximum Contaminant Levels (MCLs)

MCLs are enforceable standards promulgated under the Safe Drinking Water Act and are designed for the protection of human health. MCLs are based on laboratory or epidemiologic studies and apply to drinking water supplies consumed by a minimum of 25 persons. They are designed for prevention of human health effects associated with lifetime exposure (70 years) of an average adult (weighing 70 kg) who consumes two liters of water per day, but they also reflect the technical

feasibility of removing the contaminant from the water. These enforceable standards also reflect the fraction of toxicant expected to be absorbed by the gastrointestinal tract.

6.3.2.2 Maximum Contaminant Level Goals (MCLGs)

MCLGs are generally specified as zero for carcinogenic chemicals, based on the assumption of nonthreshold toxicity, and do not consider either the technical or economic feasibility of achieving these goals. MCLGs are nonenforceable guidelines based entirely on health effects. The MCLs are set as close to the MCLGs as is considered technically and economically feasible.

6.3.2.3 Ambient Water Quality Criteria (AWQC)

AWQCs are not enforceable Federal regulatory guidelines and are of primary utility in assessing the potential for toxic effects in aquatic organisms. They may also be used to identify the potential for human health risks. AWQCs consider the acute and chronic toxic effects in both freshwater and saltwater aquatic life, and the adverse human health effects from ingestion of both water (2 L/day) and aquatic organisms (6.5 g/day), and from the ingestion of water alone. The AWQCs for protection of human health for carcinogenic substances are based on an incremental cancer risk range of one additional case of cancer in an exposed population of 10,000,000 to 100,000 persons (i.e., the 10^{-7} to 10^{-5} range) and are generally based on older toxicologic data.

6.3.2.4 Health Advisories

Health Advisories are guidelines developed by the EPA Office of Drinking Water for nonregulated contaminants in drinking water. These guidelines are designed to consider both acute and chronic toxic effects in children (with an assumed body weight of 10 kg) who consume one liter of water per day, or in adults (with an assumed body weight of 70 kg) who consume two liters of water per day. Health Advisories are generally available for acute (1-day), subchronic (10-day), and chronic (long-term or lifetime) exposure scenarios. These guidelines are designed to consider only threshold effects and, as such, are not used to set acceptable levels of known or probable human carcinogens.

6.3.3 Summary

Table 6-4 presents values of the available Federal ARARs and dose-response parameters for both carcinogenic and noncarcinogenic chemicals. All available toxicity information is included in this table. However, if a parameter is not available, previously published values from other EPA sources are used. For example, the RfD for lead has been revoked, pending EPA's decision on its

TABLE 6-4

REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN

SITE S-5

KELLY AFB

SAN ANTONIO, TEXAS

Chemical	Safe Drinking Water Act(1)(2)		Reference Dose(3)(4) (mg/kg/day)		Ambient Water Quality Criteria(5) (mg/L)		Health Advisory(3) (mg/L)	Cancer Slope Factor(3)(4) (mg/kg/day)		EPA Weight Evidence(3)(4)
	MCL (mg/L)	MCL (mg/L)	Oral	Inhalation	Drinking Water Only	10 ⁻⁶ Risk		Oral	Inhalation	
Acetone			1x10 ⁻¹				1-Day/Child: 80 10-Day/Child: 8 Longer-term/Child: 3 Longer-term/Adult: 9 Lifetime/Adult: 0.2			D
2-Butanone			5x10 ⁻²	9x10 ⁻²						D
Benzene	0.005	0			0	6.7 x 10 ⁻⁴	1-Day/Child: 0.2 10-Day/Child: 0.2	2.9x10 ⁻²	2.9x10 ⁻²	A
Toluene	1.0	1.0	2x10 ⁻¹	6x10 ⁻¹	15		1-Day/Child: 20 10-Day/Child: 2 Longer-term/Child: 2 Longer-term/Adult: 7 Lifetime/Adult: 1			D
Ethylbenzene	0.7	0.7	1x10 ⁻¹		2.4		1-Day/Child: 30 10-Day/Child: 3 Longer-term/Child: 1 Longer-term/Adult: 3 Lifetime/Adult: 0.7			D
Xylenes	10	10	2x10 ⁰	9x10 ⁻²			1-Day/Child: 40 10-Day/Child: 40 Longer-term/Child: 40 Longer-term/Adult: 100 Lifetime/Adult: 10			D

TABLE 6-4
REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN

SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS
PAGE TWO

Chemical	Safe Drinking Water Act(1)(2)		Reference Dose(3)(4) (mg/kg/day)		Ambient Water Quality Criteria(5) (mg/L)		Health Advisory(3) (mg/L)	Cancer Slope Factor(3)(4) (mg/kg/day)		EPA Weight of Evidence(3)(4)
	MCL (mg/L)	MCL (mg/L)	Oral	Inhalation	Drinking Water Only	10 ⁻⁶ Risk		Oral	Inhalation	
Chlorobenzene	0.1	0.1	2x10 ⁻²	5x10 ⁻³	0.488		1-Day/Child: 2 10-Day/Child: 2 Longer-term/Child: 2 Longer-term/Adult: 7 Lifetime/Adult: 0.1			D
Tetrachloroethene	0.005	0	1x10 ⁻²		0	8.8 x 10 ⁻⁴	1-Day/Child: 2 10-Day/Child: 2 Longer-term/Child: 1 Longer-term/Adult: 5	5.1x10 ⁻²	1.8x10 ⁻²	B2
Trichloroethene	0.005	0			0	2.8 x 10 ⁻³		1.1x10 ⁻²	1.7x10 ⁻²	B2
trans-1,2-Dichloroethene	0.1	0.1	2x10 ⁻²				1-Day/Child: 20 10-Day/Child: 2 Longer-term/Child: 2 Longer-term/Adult: 6 Lifetime/Adult: 0.1			D
1,1-Dichloroethene	0.007	0.007	9x10 ⁻³		0	3.3 x 10 ⁻⁵	1-Day/Child: 2 10-Day/Child: 1 Longer-term/Child: 1 Longer-term/Adult: 4 Lifetime/Adult: 0.007	6.0x10 ⁻¹	1.2x10 ⁰	C
Vinyl chloride	0.002	0			0	2.0 x 10 ⁻³	1-Day/Child: 3 10-Day/Child: 3 Longer-term/Child: 0.01 Longer-term/Adult: 0.050	1.9x10 ⁻⁰	2.94x10 ⁻¹	A

TABLE 6-4
REGULATORY REQUIREMENTS AND DOSE-RESPONSE PARAMETERS FOR CHEMICALS OF CONCERN

SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS
PAGE THREE

Chemical	Safe Drinking Water Act(1)(2)		Reference Dose(3)(4) (mg/kg/day)		Ambient Water Quality Criteria(5) (mg/L)		Health Advisory(3) (mg/L)	Cancer Slope Factor(3)(4) (mg/kg/day)		EPA Weight of Evidence(3)(4)
	MCL (mg/L)	MCL (mg/L)	Oral	Inhalation	Drinking Water Only	10 ⁻⁶ Risk		Oral	Inhalation	
1,1,1-Trichloroethane	0.2	0.2	9x10 ⁻²	3x10 ⁻¹	19		1-Day/Child: 100 10-Day/Child: 40 Longer-term/Child: 40 Longer-term/Adult: 100 Lifetime/Adult: 0.2			D
1,1-Dichloroethane			1x10 ⁻¹	1x10 ⁻¹						C
Methylene chloride	0.005	0	6x10 ⁻²	9x10 ⁻¹			1-Day/Child: 10 10-Day/Child: 2	7.5x10 ⁻³	1.4x10 ⁻²	B2
Carbon disulfide			1x10 ⁻¹	3x10 ⁻³						D
Vinyl acetate			1x10 ⁰	6x10 ⁻²						
2-Methylphenol			5x10 ⁻²							C
Naphthalene			4x10 ⁻³				1-Day/Child: 0.5 10-Day/Child: 0.5 Longer-term/Child: 0.4 Longer-term/Adult: 1 Lifetime/Adult: 0.020			D
Lead	0.015(a)	0	1.4x10 ⁻³ (b)	4.3x10 ⁻⁴ (b)	50					B2

(1) U.S. EPA, April 1991

(2) U.S. EPA, June 7, 1991

(3) U.S. EPA, January 1991

(4) U.S. EPA, 1991

(5) U.S. EPA, October 1986

(a) Action Level developed for public water supply systems, exceedance of which at the source requires corrosion control measures.

(b) Reference Dose has been revoked.

carcinogenicity. However, because lead is considered to be a site-related contaminant, the older published value is used. If the intake of a chemical exceeds these standards or guidelines, a receptor may experience adverse health effects. Expected intakes of each chemical are presented in the Exposure Assessment section (Section 6.4).

6.4 EXPOSURE ASSESSMENT

The purpose of this section is to evaluate the potential for human exposure to the hazardous chemicals in the environmental media at Site S-5. This section characterizes the exposed populations, identifies actual or potential exposure routes, and provides exposure estimates. The nature and extent of contamination upon which the exposures are based is presented in Section 4.0.

To determine whether there is an actual or a potential exposure in the future at the site, one must consider the most likely pathways of contaminant release and transport, as well as the human and environmental activity patterns in the area. A complete exposure pathway has three components: (1) a source of chemicals that can be released to the environment; (2) a route of contaminant transport through an environmental medium; and (3) an exposure or contact point for a human or environmental receptor. These components are addressed in the following subsections.

There are no plans to develop the site for residential use because of its proximity to the flightline, according to the base master plan. Consequently, an exposure scenario that addresses future residential land use will not be addressed at this time.

6.4.1 Exposure Routes

There are three environmental media at Site S-5 through which identified receptors can be either directly or indirectly exposed to site-related contaminants--air, soil, and groundwater. This section identifies the receptors most at risk through each exposure pathway. Exposure pathways are summarized in Table 6-5.

6.4.1.1 Air

Exposures to contaminants in air could occur in two ways--volatilization or fugitive dust emissions. However, in the hot, dry environment of San Antonio, volatilization is unlikely from old surface spills. Unless there is a significant source of volatiles very near the ground surface (which is not the case at Site S-5), volatilization is not a significant exposure route.

TABLE 6-5

**SUMMARY OF EXPOSURE PATHWAYS
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Medium	Route of Exposure	Potential Receptors	Pathway Complete?	Exposed Population Estimate
Air	Inhalation of Dust	Base Personnel	Yes. Personnel exposed during maintenance or construction.	20
	Inhalation of Volatile Emissions	Offsite Residents	Yes. Dust can be carried off site.	<100 0
		Base Personnel	No. Surface soils contain very low concentration of volatile organics.	
Soil	Dermal Contact/Incidental Ingestion	Base Personnel	Yes. Personnel exposed during maintenance, construction, or employment. Because of site location near flightline, no dependents or local residents exposed.	20
	Dermal Contact/Ingestion	Residents	No. Base master plan in effect calls for continued industrial use of this area.	0
Groundwater	Ingestion	Base Personnel	Yes. A well could be installed to serve the immediate vicinity.	0*
	Ingestion/Inhalation/Dermal Contact	Base Residents/Dependents	Yes. A well could be installed to serve residential areas of the base.	0*
		Base Dependents	Yes. Sprinkler systems exist downgradient that extract water from alluvial aquifer.	0*
Surface Water	Ingestion/Dermal Contact	Base Dependents/Local Residents	No. No surface water bodies nearby or in immediate downgradient area.	0

*No persons are currently exposed. This is a hypothetical exposure route.

The action of the wind on the fine-grained soils can generate fugitive dust, which can be carried downwind. Downwind receptors are most likely to be affected by dust in the air. This exposure route considers both deposition in the respiratory tract as well as the ingestion of larger particles initially inhaled. This scenario is evaluated only under existing land use conditions using the surface soil concentrations in the estimation of intakes for the following receptors: (1) base personnel engaged in maintenance activities; and (2) offsite adult and child receptors. Subsurface soil concentrations are used in the estimation of intakes for base personnel engaged in construction activities.

6.4.1.2 Soil

Direct contact with contaminated soil can result in a dermal exposure. For example, base personnel working outdoors can get contaminated soil on their skin. Organic chemicals in soil are dermally absorbed to some extent, but metals in soil are not generally considered to be absorbed. In addition, incidental ingestion of soil can occur after hand-to-mouth contact by receptors.

These exposure routes are applicable to adult base personnel involved in landscape maintenance (exposure to surface soil contaminants) and those involved in construction activities (exposure to surface and subsurface soil contaminants). The presence of contaminated soil at depths greater than 12 feet will not affect the exposures because this soil would not be exposed during construction.

There are some plans for construction of a fire station on this site. In this case, base personnel could be exposed on a more regular basis over a longer period of time.

No residents (adults or children) are evaluated for this exposure route because of the existence of a base master plan and the fact that the site is located along the flightline and is therefore highly unlikely to be developed for residential uses at any time in the foreseeable future.

6.4.1.3 Groundwater

Infiltrating precipitation can leach contaminants from surface and subsurface soils. Once dissolved contaminants reach the groundwater, they are transported downgradient. Shallow wells in the direction of groundwater flow are potential withdrawal points.

Three potential groundwater use scenarios were developed for Site S-5. The first scenario evaluates the potential use of groundwater in the immediate vicinity of the site itself. This scenario assumes that a base supply well could be installed to serve particular site facilities and that base personnel could subsequently use the water for drinking purposes only. The second scenario assumes that a

base supply well could be installed that could serve residential areas of the base, thereby affecting both adults and children. These residential receptors could be exposed to groundwater contamination via ingestion, inhalation of volatiles emitted during showering (adults only), and dermal contact while showering or bathing. Because there are no supply wells in the area (or in the alluvial aquifer), the hypothetical scenarios of future groundwater use are therefore worst-case situations and were developed for full evaluation purposes only.

A third scenario was developed to evaluate potential future exposures of base dependents who may be exposed while playing under sprinklers. This scenario uses only those contaminants associated with the fuel spill at Building 1680, and the exposure concentrations are based on groundwater modeling rather than measured concentrations.

6.4.2 Exposure Estimates

The estimation methods and models used in this section are consistent with current EPA risk assessment guidance (U.S. EPA, December 1989) and with previous work done at Kelly AFB. Exposure estimates associated with each exposure route are presented below. All exposure scenarios incorporate the representative contaminant concentrations in the estimates of intakes. Therefore, only one exposure scenario was developed for each exposure route and receptor combination.

Noncarcinogenic risks are estimated using the concept of an average annual exposure. The intake incorporates terms describing the exposure time and/or frequency that represent the number of hours per day and the number of days per year that exposure occurs. This is used with a term known as the averaging time, which annualizes the exposure frequency and duration by dividing by 365 days per year of exposure. Noncarcinogenic risks are generally greater for children than for adults because of their much lower body weights and only slightly lower ingestion rates.

Carcinogenic risks, on the other hand, are calculated as an incremental lifetime risk and therefore incorporate terms to represent the exposure duration (years) over the course of a lifetime (70 years). These terms are presented in the equations used to calculate potential cancer risks but cancel out in the calculation of noncarcinogenic risks. Carcinogenic risks are not calculated for children because the risks for children are always less than for adults because of shorter exposure durations at lower body weights.

6.4.2.1 Air

Exposures to fugitive dust are estimated for base employees engaged in maintenance and construction activities at Site S-5. In addition, offsite residents (both children and adults) may be exposed at their homes to fugitive dust emitted from the site.

An emission model (Cowherd et al., 1984) is used to estimate the concentrations of respirable particulates in the air based on wind speed, vegetative cover, size of the source area, etc. The conditions and assumptions employed in this model are contained in Appendix E. The source area for the base personnel exposure scenario is assumed to be the entire unpaved surface area of the site (3,000 m²). The source size for the base personnel construction exposure scenario is assumed to be 1,600 m².

Chemical-specific intakes are then estimated using the following expression (U.S. EPA, December 1989):

$$IEX = C_{air} \times IR \times ABS \times ET \times EF \times ED / (BW \times AT)$$

where:	IEX	=	inhalation exposure dose (mg/kg/day)
	C _{air}	=	air concentration of chemical (mg/m ³)
	IR	=	inhalation rate (m ³ /hour)
	ABS	=	absorption rate (decimal fraction)
	ET	=	exposure time (hours/day)
	EF	=	exposure frequency (days/year)
	ED	=	exposure duration (years)
	BW	=	body weight (kg)
	AT	=	averaging time or period of exposure (days)

The inhalation rate is specified as 0.83 m³/hour for adult residents and 0.42 m³/hour for children. An inhalation rate of 30 m³/day (1.2 m³/hour) was used for adults engaged in maintenance or construction activities. Absorption in the lungs is 12.5 percent, and 62.5 percent of the particles removed from the lungs is subsequently swallowed and completely absorbed in the gastrointestinal tract. The following exposure times were used:

- Adult employees = 8 hours/day
- Adult offsite residents = 16 hours/day
- Child offsite residents = 24 hours/day

Exposure frequencies are specified as 24 days/year for base maintenance employees (based on bimonthly landscape maintenance schedules), 30 days/year for base construction employees (based on an estimate of short-duration repair/remodel projects), and 350 days/year for residents. Exposure duration for base personnel is estimated to be 20 years for the maintenance scenario and one time (e.g., one year) for the construction scenario. Offsite receptors are expected to be exposed over a 30-year period, which is the 90th percentile for time at one residence (U.S. EPA, December 1989). The body weight for adults is assumed to be 70 kg, and for children, a 10-kg body weight was used.

Table 6-6 presents a summary of the input parameters for the fugitive dust scenarios. Estimated intakes are presented in Table 6-7.

6.4.2.2 Soil

Physical contact with contaminated soils can result in the dermal absorption of chemicals. Exposures through this route are estimated as follows (U.S. EPA, December 1989):

$$DEX = C \times SA \times AF \times ABS \times EF \times ED / (BW \times AT \times 10^6)$$

where:	DEX	=	dermally absorbed dose (mg/kg/day)
	C	=	contaminant concentration in soil (mg/kg)
	SA	=	exposed surface area of skin (cm ² /day)
	AF	=	soil adherence per unit skin area (mg/cm ²)
	ABS	=	absorption factor (decimal fraction)
	EF	=	exposure frequency (days/year)
	ED	=	exposure duration (years)
	BW	=	body weight (kg)
	AT	=	averaging time or period of exposure (days)
	10 ⁶	=	conversion factor (mg/kg)

Three exposure scenarios were developed for this exposure route. The first scenario assumes that adult base personnel will be exposed to site surface soil during landscape maintenance activities. The second scenario assumes that adult base personnel will be exposed to subsurface soil during short-term construction activity. The third assumes long-term exposure to subsurface soil if the firehouse is constructed on site.

TABLE 6-6
EXPOSURE ASSESSMENT SUMMARY - FUGITIVE DUST EXPOSURE
SITE S-5
KELLY AFB, SAN ANTONIO, TEXAS

Fugitive Dust Exposure (Residents)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	Used to calculate contaminant emission rate (mg/m ³)
IR	Inhalation Rate	Adult - 0.83 m ³ /hr Child - 0.42 m ³ /hr	USEPA, May 1989
ABS	Absorption in Lungs and Gut	Lungs - 0.125 Gut - 0.625	Schaum, 1984
ET	Exposure Time	Adult - 16 hr/day Child - 24 hr/day	Professional judgment
EF	Exposure Frequency	350 days/yr	Daily exposure (USEPA, March 25, 1991)
ED	Exposure Duration	Adult - 30 years Child - 6 years	USEPA, December 1989
BW	Body Weight	Adult - 70 kg Child - 10 kg	Convention (USEPA, December 1989)
AT	Averaging Time	10,950 days 2,190 days 25,550 days	Noncarcinogenic risks - adults Noncarcinogenic risks - child Carcinogenic risks - adults

TABLE 6-6
EXPOSURE ASSESSMENT SUMMARY - FUGITIVE DUST EXPOSURE
PAGE TWO

Fugitive Dust Exposure (Employees - Maintenance)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL(1) (mg/kg)	Used to calculate contaminant emission rates (mg/m ³)
IR	Inhalation Rate	1.2 m ³ /hr	USEPA, May 1989
ABS	Absorption in Lungs and Gut	Lungs - 0.125 Gut - 0.625	Schaum, 1984
ET	Exposure Time	8 hr/day	Professional judgment
EF	Exposure Frequency	24 days/yr	Two days per month; professional judgment
ED	Exposure Duration	20 years	Working lifetime; civilian employees or career military
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	7,300 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-6
EXPOSURE ASSESSMENT SUMMARY - FUGITIVE DUST EXPOSURE
PAGE THREE

Fugitive Dust Exposure (Employees - Construction)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	Used to calculate contaminant emission rates (mg/m ³)
IR	Inhalation Rate	1.2 m ³ /hr	USEPA, May 1989
ABS	Absorption in Lungs and Gut	Lungs - 0.125 Gut - 0.625	Schaum, 1984
ET	Exposure Time	8 hr/day	Professional judgment
EF	Exposure Frequency	30 days/yr	Professional judgment
ED	Exposure Duration	1 year	One time exposure; professional judgment
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	365 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

(1) Upper 95 percent confidence limit (UCL) of arithmetic average, or maximum concentration if UCL exceeds maximum.

TABLE 6-7

DOSE ESTIMATES - FUGITIVE DUST EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Chemical	Dose Estimates ⁽¹⁾ (mg/kg/day)		
	Adult Resident	Child Resident	Adult Employee (Maintenance)
Toluene	8.9×10^{-12}	4.7×10^{-11}	1.6×10^{-12}
Ethylbenzene	1.7×10^{-11}	8.9×10^{-11}	3.0×10^{-12}

(1) Calculations provided in Appendix E.

(2) No Reference Dose available for this chemical or exposure route.

The exposure concentration for all soil contact scenarios is the representative concentration calculated as shown in Section 6.2.4. Only the surface (0.5 to 2.5 feet deep) or subsurface soil (less than 12 feet deep) sample results are used in determining the representative concentrations for soil contact.

The approximate exposed skin area of an adult wearing a short-sleeved, open-necked shirt, pants, shoes, and no gloves or hat was set at 3,000 cm² (U.S. EPA, May 1989). The soil adherence factor was set at 1.45 mg/cm² (U.S. EPA, December 1989). It was also assumed that ten percent of volatiles in soil are available for dermal absorption and that metals in soil are not dermally absorbed. This factor accounts for the resistance to mass transfer from the soil to the skin surface, as well as to transport through the skin. These estimates are considered to be reasonable because studies have shown that less than ten percent of most chemical substances are percutaneously absorbed even after topical administration (Feldman and Maibach, 1970).

The exposure frequency and exposure duration for base personnel engaged in landscape maintenance is specified as 24 days/year and 20 years, respectively, as described for the air exposure routes. Base personnel engaged in construction activities are assumed to be exposed 30 days every 20 years. This construction scenario assumes that any single area will not be disturbed more than once every 20 years. Fire station personnel are assumed to be exposed 250 days/year over 20 years. Twenty years is considered to be the working lifetime of either a civilian employee or a career military person. The receptor body weight is set at 70 kg for adults.

Exposure to soil can also result in a minor amount of incidental ingestion after hand-to-mouth contact. Intakes through this route are estimated as follows (U.S. EPA, December 1989):

$$IEX = C \times IR \times F_i \times EF \times ED / (BW \times AT \times 10^6)$$

where:

- IEX = ingestional exposure dose (mg/kg/day)
- C = exposure concentration in soil (mg/kg)
- IR = soil ingestion rate (mg/day)
- F_i = fraction ingested from contaminated source (decimal fraction)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time or period of exposure (days)
- 10⁶ = conversion factor (mg/kg)

The average daily rate of soil ingestion for adults is 100 mg/day (U.S. EPA, December 1989), and 50 percent of this amount is assumed to be from the contaminated source. The exposure frequency and exposure duration for base personnel engaged in landscape maintenance is specified as 24 days/year and 20 years, respectively. Base personnel engaged in construction activities are assumed to be exposed for one 30-day period over their working lifetime of 20 years. Fire station personnel are assumed to be exposed 250 days/year over a period of 20 years. The receptor body weight for an adult is 70 kg.

A summary of the soil exposure assessment input parameters for dermal contact and incidental ingestion is presented in Table 6-8. Intakes for both soil exposure scenarios are presented in Tables 6-9 and 6-10.

6.4.2.3 Groundwater

Three specific exposure routes are associated with potential groundwater use in the Site S-5 area. These exposure routes include ingestion, inhalation of volatiles emitted during showering, and dermal contact. The methods used to assess these routes of exposure are discussed in the following text.

Ingestional exposures are characterized using the following expression (U.S. EPA, December 1989):

$$IEX = C \times IR \times EF \times ED / (BW \times AT)$$

where:

- IEX = ingestional exposure dose (mg/kg/day)
- C = groundwater exposure concentration (mg/L)
- IR = ingestion rate (L/day)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time (days)

As stated previously, there are three potential groundwater use scenarios for the site. The first scenario assumes that a well could be installed to serve only the site area, in which case only base employees could be exposed for only a portion of their total daily water use. The second scenario assumes that a well could be installed to serve residential areas of the base, which would expose both children and adults to the contaminants. The third assumes that children can be exposed while playing under sprinklers. The first two scenarios use as exposure concentrations the representative

TABLE 6-8

**EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
SITE S-5
KELLY AFB, SAN ANTONIO, TEXAS**

Dermal Contact with Surface Soil (Employees - Maintenance)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	EPA guidance (USEPA, December 1989)
AV	Exposed Surface Area of Skin	3,000 cm ² /day	Adult wearing short-sleeved, open-necked shirt; pants, shoes (USEPA, May 1989)
AF	Soil-to-Skin Adherence Factor	1.45 mg/cm ²	Value for commercial potting soil (USEPA, December 1989)
ABS	Absorption Factor (dimensionless)	Volatiles - 0.10 Metals - 0.0	Accounts for desorption from soil and percutaneous absorption (Feldman and Maibach, 1970)
EF	Exposure Frequency	24 days/yr	Two exposures per month; professional judgment
ED	Exposure Duration	20 years	Working lifetime, civilian employees or career military
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	7,300 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-8
EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
PAGE TWO

Incidental Ingestion of Surface Soil (Employees - Maintenance)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL(1) (mg/kg)	EPA guidance (USEPA, December 1989)
IR	Ingestion Rate	100 mg/day	Suggested value; brief exposures only; EPA guidance (USEPA, December 1989)
FI	Fraction Ingested from Contaminated Source	0.50	Professional judgment
EF	Exposure Frequency	24 days/yr	Two exposures per month; professional judgment
ED	Exposure Duration	20 years	Working lifetime, civilian employees or career military
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	7,300 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-8
EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
PAGE THREE

Dermal Contact with Surface/Subsurface Soil (Employees - Construction)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	EPA guidance (USEPA, December 1989)
AV	Exposed Surface Area of Skin	3,000 cm ² /day	Adult wearing short-sleeved, open-necked shirt; pants, shoes (USEPA, May 1989)
AF	Soil-to-Skin Adherence Factor	1.45 mg/cm ²	Value for commercial potting soil (USEPA, December 1989)
ABS	Absorption Factor (dimensionless)	Volatiles - 0.10 Metals - 0.0	Accounts for desorption from soil and percutaneous absorption (Feldman and Maibach, 1970)
EF	Exposure Frequency	30 days/yr	Professional judgment
ED	Exposure Duration	1 year	One time exposure; professional judgment
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	365 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-8
EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
PAGE FOUR

Incidental Ingestion of Surface/Subsurface Soil (Employees - Construction)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	EPA guidance (USEPA, December 1989)
IR	Ingestion Rate	100 mg/day	Suggested value; brief exposures only; EPA guidance (USEPA, December 1989)
FI	Fraction Ingested from Contaminated Source	0.50	Professional judgment
EF	Exposure Frequency	30 days/yr	Professional judgment
ED	Exposure Duration	1 year	One time exposure professional judgment
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	365 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-8
EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
PAGE FIVE

Dermal Contact with Surface/Subsurface Soil (Employees - Fire Station)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	EPA guidance (USEPA, December 1989)
AV	Exposed Surface Area of Skin	3,000 cm ² /day	Adult wearing short-sleeved, open-necked shirt; pants, shoes (USEPA, May 1989)
AF	Soil-to-Skin Adherence Factor	1.45 mg/cm ²	Value for commercial potting soil (USEPA, December 1989)
ABS	Absorption Factor (dimensionless)	Volatiles - 0.10 Metals - 0.0	Accounts for desorption from soil and percutaneous absorption (Feldman and Maibach, 1970)
EF	Exposure Frequency	250 days/yr	Professional judgment
ED	Exposure Duration	20 years	Professional judgment
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	7,300 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

TABLE 6-8
EXPOSURE ASSESSMENT SUMMARY - DIRECT CONTACT WITH SOIL
PAGE SIX

Incidental Ingestion of Surface/Subsurface Soil (Employees - Fire Station)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg)	EPA guidance (USEPA, December 1989)
IR	Ingestion Rate	100 mg/day	Suggested value; brief exposures only; EPA guidance (USEPA, December 1989)
FI	Fraction Ingested from Contaminated Source	0.50	Professional judgment
EF	Exposure Frequency	250 days/yr	Professional judgment
ED	Exposure Duration	20 years	One time exposure professional judgment
BW	Body Weight	70 kg	Adult receptors; convention (USEPA, December 1989)
AT	Averaging Time	7,300 days 25,550 days	Noncarcinogenic risks Carcinogenic risks

(1) Upper 95 percent confidence limit (UCL) of arithmetic average, or maximum concentration if UCL exceeds maximum.

TABLE 6-9

**DOSE ESTIMATES - SURFACE SOIL CONTACT
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Chemical	Dose Estimates ⁽¹⁾ (mg/kg/day)	
	Adult Employee - Maintenance	
	Dermal Absorption	Incidental Ingestion
Toluene	1.4×10^{-7}	1.6×10^{-8}
Ethylbenzene	2.6×10^{-7}	3.0×10^{-8}

(1) Calculations provided in Appendix E.

TABLE 6-10

**DOSE ESTIMATES - SURFACE/SUBSURFACE SOIL EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Chemical	Dose Estimates ⁽¹⁾ (mg/kg/day)				
	Adult Employee - Construction			Fire Station Personnel	
	Dermal Absorption	Incidental Ingestion	Inhalation	Dermal Absorption	Incidental Ingestion
Benzene	1.4x10 ⁻⁸	1.6x10 ⁻⁹	1.7x10 ⁻¹²	1.1x10 ⁻⁷	1.3x10 ⁻⁸
Toluene	4.3x10 ⁻⁸	5.0x10 ⁻⁹	5.2x10 ⁻¹²	3.6x10 ⁻⁷	4.2x10 ⁻⁸
Ethylbenzene	7.1x10 ⁻⁸	8.2x10 ⁻⁹	8.6x10 ⁻¹²	6.0x10 ⁻⁷	6.8x10 ⁻⁸
Tetrachloroethene	1.8x10 ⁻⁸	2.1x10 ⁻⁹	2.2x10 ⁻¹²	1.5x10 ⁻⁷	1.8x10 ⁻⁸
Lead	NA	4.7x10 ⁻⁷	4.9x10 ⁻¹⁰	NA	3.9x10 ⁻⁶

(1) Calculations provided in Appendix E.

NA Not applicable; inorganics are assumed not to be dermally absorbed.

concentration calculated for wells within the plume area. Wells that are beyond the limits of all plumes (e.g., no contaminants detected) were excluded from the calculations. These scenarios are hypothetical and as such were intended to represent worst-case conditions. The sprinkler scenario is most likely (of the three) to actually occur. Downgradient of the spill area, sprinklers are used for lawn care, and if the plume continues to migrate, exposures could occur. The contaminant concentrations used in this exposure route are based on a groundwater modeling exercise conducted to determine realistic downgradient conditions over time.

Under the base employee scenario, an ingestion rate of one L/day and an exposure frequency of 250 days/year are assumed. This scenario also uses an exposure duration of 20 years and a lifetime of 70 years.

Under the residential use scenario, the following input parameters are used to estimate intakes. Adult residents are assumed to ingest two liters of water per day, 350 days/year over a 30-year exposure period (U.S. EPA, December 1989). Child residents are assumed to ingest one liter of water per day, 350 days/year. Body weights are specified as 70 kg for adults and 10 kg for children.

For the recreational scenario, an ingestion rate of 0.25 L/day was assumed for a 30-kg child (ages 4 to 11). Exposures are estimated 50 days/year for 8 years.

Inhalational exposures during showering were estimated using a mass transfer model developed specifically for this exposure route, in combination with an intake estimation model. The mass transfer model accounts for inhalation that occurs during a shower and after the shower while the receptor remains in the bathroom. The method employed is as follows (U.S. EPA, December 1989; Foster and Chrostowski, 1987):

$$IEX = S \times IR \times K \times EF \times ED / (BW \times AT \times R_a \times 10^6)$$

$$K = D_s + \exp(-R_a \times D_t) / R_a - \exp[R_a \times (D_s - D_t)] / R_a$$

where:

- IEX = inhalational exposure dose (mg/kg/day)
- S = volatile chemical generation rate ($\mu\text{g}/\text{m}^3/\text{min}$)
- IR = inhalation rate (L/min)
- EF = exposure frequency (days⁻¹)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time or period of exposure (days)
- R_a = air exchange rate (min⁻¹)

K = mass transfer coefficient
 D_s = shower duration (min)
 D_t = total time in bathroom (min)
 10^6 = conversion factor ($\mu\text{g}/\text{mg}/\text{L}/\text{m}^3$)

The volatile chemical generation rate was estimated using the Foster and Chrostowski mass transfer model, which is based on two-phase film theory. The model employs contaminant-specific mass transfer coefficients, Henry's Law Constants, droplet diameter, drop time, viscosity, temperature, etc. Specific details regarding the application of the mass transfer model are included in Appendix E.

It is assumed that small children do not take showers and are therefore not exposed in this manner. In addition, this exposure route only applies to the residential use scenario.

The inhalation rate was specified as 14 L/min for a 70-kg adult. The exposure frequency was specified as 0.96 day⁻¹ (i.e., one shower per day, for 350 days/year), and the exposure duration was specified as 30 years over a 70-year lifetime. The air exchange rate was specified as 0.0083 min⁻¹, the shower duration as 15 minutes, and the total time in the bathroom as 20 minutes.

The inhalation rate was also specified as 14 L/min for 30-kg children actively playing outdoors. Exposure frequencies and durations were specified for ingestion. The air exchange rate was specified as 5 min⁻¹ (which is the maximum accepted by the model) and considering an average wind speed of 4.2 m/sec. Exposure time is 20 minutes.

Dermal exposures during bathing (child residents) or showering (adult residents) are estimated as follows (U.S. EPA, December 1989):

$$\text{DEX} = C \times \text{PC} \times \text{AV} \times \text{ET} \times \text{EF} \times \text{ED} / (\text{BW} \times \text{AT} \times 10^3)$$

where: DEX = dermal exposure dose (mg/kg/day)
 C = groundwater exposure concentration (mg/L)
 PC = dermal permeability constant of water (cm/hour)
 AV = skin surface area available for contact (cm²)
 ET = exposure time (hours/day)
 EF = exposure frequency (days/year)
 ED = exposure duration (years)
 BW = body weight (kg)

AT = averaging time or period of exposure (days)
10³ = conversion factor (cm³/L)

This approach is based on the assumption that groundwater contaminants are present in dilute form and that percutaneous absorption is controlled by the flux of water. The permeability constant is assumed to be 0.0008 cm/hour (U.S. EPA, April 1988). Skin surface area available for contact is specified as 19,400 cm² for adults and 7,280 cm² for child residents, and 11,000 cm² for older children playing outdoors (U.S. EPA, December 1989). The exposure time is specified as 0.25 hours/day, and the exposure frequency is set at 350 days/year for indoor exposures and 0.33 hr/day, 50 days/year for outdoor exposures. Exposure duration is set at 30 years for residents and 8 years (ages 4 to 11) for children playing outdoors.

Table 6-11 presents a summary of the input parameters for the three groundwater exposure routes described above. Estimated intakes are presented in Table 6-12.

6.5 RISK CHARACTERIZATION

Potential human health risks resulting from the exposures outlined in the preceding sections are characterized on a quantitative basis in this section. Quantitative risk estimates are generated based on risk assessment methods outlined in current EPA guidance (U.S. EPA, December 1989). Noncarcinogenic risk estimates are presented in the form of Hazard Quotients and Hazard Indices that are determined through comparison of estimated intakes with published Reference Doses. Incremental cancer risk estimates are provided in the form of dimensionless probabilities based on Cancer Slope Factors.

Estimated human intakes were developed for each of the specific exposure routes discussed in the preceding sections. Both carcinogenic and noncarcinogenic risks are summarized for each exposure route on a series of tables in this section. Detailed calculations are provided in Appendix E.

Noncarcinogenic risk is assessed using the concept of Hazard Quotients and Hazard Indices. The Hazard Quotient is the ratio of the estimated intake and the Reference Dose (RfD) for a selected chemical of concern, as follows:

$$\text{Hazard Quotient} = \text{Dose} / \text{RfD}$$

A Hazard Index is generated by summing the individual Hazard Quotients for the chemicals of concern. If the value of the Hazard Index exceeds unity (1.0), there is a potential noncarcinogenic

TABLE 6-11
EXPOSURE ASSESSMENT SUMMARY - GROUNDWATER
SITE S-5
KELLY AFB, SAN ANTONIO, TEXAS

Ingestion of Groundwater (Residents and Employees)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/L) (wells in plume only)	EPA guidance (USEPA, December 1989).
IR	Ingestion Rate	Adult (resident) - 2L/day Adult (employee) - 1L/day Child (resident) - 1L/day Child (recreation) - 0.25 L/day	Convention; EPA guidance (USEPA, December 1989); Professional judgment.
EF	Exposure Frequency	350 days/year (resident) 250 days/year (employee) 50 days/year (recreation)	USEPA, March 25, 1991; Professional judgment.
ED	Exposure Duration	30 years (adult resident) 6 years (child resident) 20 years (employee) 8 years (recreation)	Convention (USEPA, December 1989) Working lifetime, civilian or career military; Professional judgment.
BW	Body Weight	70 kg (adult employee or resident) 10 kg (child resident) 30 kg (recreation)	Convention (USEPA, December 1989) USEPA, December 1989
AT	Averaging Time	10,950 days 2,190 days 7,300 days 2,950 days 25,550 days	Noncarcinogenic risks - adult residents Noncarcinogenic risks - child resident Noncarcinogenic risks - adult employees Noncarcinogenic risks - child (recreation) Carcinogenic risks

TABLE 6-11
EXPOSURE ASSESSMENT SUMMARY - GROUNDWATER
PAGE TWO

Inhalation of Volatiles During Showering (Residents Only)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/kg) (wells in plume only)	Used to calculate volatile chemical generation rate ($\mu\text{g}/\text{m}^3/\text{min}$).
H	Henry's Law Constant	Contaminant - specific	Required for model application
K _g , K _l	Gas and Liquid Phase Mass Transfer Coefficients	Contaminant - specific	Required for model application.
D _s	Shower Duration Play Duration	15 min 20 min	Professional judgment. Professional judgment.
D _t	Total Time in Bathroom	20 min	Professional judgment.
R _a	Air Exchange Rate	0.0083 min ⁻¹ (shower) 5/min ⁻¹ (recreation)	Foster and Chrostowski 1987. Professional judgment based on fact exposure occurs outdoors.
IR	Inhalation Rate	14 L/min	USEPA, December 1989. Children not exposed via showering.
EF	Exposure Frequency	0.96 day ⁻¹ (350 days/yr) 50 days/year (recreation)	One shower per day. Professional judgment.
ED	Exposure Duration	30 years 8 years	USEPA, December 1989. Professional judgment.
BW	Body Weight	70 kg 30 kg	Convention (USEPA, December 1989).
AT	Averaging Time	10,950 days 2,950 days 25,550 days	Noncarcinogenic risks - residents. Noncarcinogenic risks - recreation. Carcinogenic risks.

TABLE 6-11
EXPOSURE ASSESSMENT SUMMARY - GROUNDWATER
PAGE THREE

Dermal Contact with Groundwater (Residents Only)			
Input Parameter	Description	Value	Rationale
C	Exposure Concentration	UCL ⁽¹⁾ (mg/L) (wells in plume only)	EPA guidance (USEPA, December 1989).
AV	Exposed Surface Area of Skin	Adult - 19,400 cm ² Child - 7,280 cm ² Child (recreation) - 11,000 cm ²	USEPA, December 1989.
PC	Permeability Constant	0.0008 cm/hr	Flux controlled by permeation of water (USEPA, April 1988).
ET	Exposure Time	0.25 hr/day 0.33 hr/day	Fifteen minute shower or bath; professional judgment. Professional judgment.
EF	Exposure Frequency	350 days/year 50 days/year	Shower/bath every day (USEPA, March 25, 1991). Professional judgment.
ED	Exposure Duration	Adult - 30 years Child - 6 years Child (recreation) - 8 years	USEPA, December 1989. Professional judgment.
BW	Body Weight	Adult - 70 kg Child - 10 kg Child (recreation) - 30 kg	USEPA, December 1989.
AT	Averaging Time	10,950 days 2,190 days 2,950 days 25,550 days	Noncarcinogenic risks - adult. Noncarcinogenic risks - child resident. Noncarcinogenic risks - child (recreation). Carcinogenic risks.

(1) Upper 95 percent confidence limit (UCL) of arithmetic average, or maximum concentration if UCL exceeds maximum.

TABLE 6-12

DOSE ESTIMATES - GROUNDWATER EXPOSURE

SITE S-5

KELLY AFB

SAN ANTONIO, TEXAS

Chemical	Dose Estimates (mg/kg/day) ⁽¹⁾						
	Adult Resident		Child Resident		Adult Employee	Child (Recreation)	
	Ingestion and Dermal Absorption	Inhalation	Ingestion	Dermal	Ingestion	Ingestion and Dermal Absorption	Inhalation
Acetone	9.6x10 ⁻⁴	8.7x10 ⁻⁵	3.3x10 ⁻³	4.9x10 ⁻⁶	3.4x10 ⁻⁴	5.4x10 ⁻³	2.4x10 ⁻³
2-Butanone	8.2x10 ⁻⁵	4.3x10 ⁻⁶	2.9x10 ⁻⁴	4.2x10 ⁻⁷	2.9x10 ⁻⁵	2.1x10 ⁻⁴	5.6x10 ⁻⁵
Benzene	5.2x10 ⁻³	2.5x10 ⁻³	1.8x10 ⁻²	2.6x10 ⁻⁵	1.8x10 ⁻³	4.0x10 ⁻⁵	1.0x10 ⁻⁴
Toluene	4.1x10 ⁻⁴	1.9x10 ⁻⁴	1.4x10 ⁻³	2.7x10 ⁻⁶	1.9x10 ⁻⁴	7.4x10 ⁻⁴	1.8x10 ⁻³
Ethylbenzene	7.1x10 ⁻³	3.1x10 ⁻³	2.5x10 ⁻²	3.6x10 ⁻⁵	2.5x10 ⁻³	2.5x10 ⁻⁵	5.8x10 ⁻⁵
Xylenes	9.0x10 ⁻⁴	3.9x10 ⁻⁴	2.3x10 ⁻³	4.6x10 ⁻⁶	3.2x10 ⁻⁴	4.7x10 ⁻⁵	1.1x10 ⁻⁵
Chlorobenzene	5.5x10 ⁻⁵	2.3x10 ⁻⁵	1.9x10 ⁻⁴	2.8x10 ⁻⁷	2.0x10 ⁻⁵	(2)	(2)
1,1,1-Trichloroethane	2.0x10 ⁻³	8.1x10 ⁻⁴	7.0x10 ⁻³	1.0x10 ⁻⁵	7.1x10 ⁻⁴	(2)	(2)
1,1-Dichloroethane	9.0x10 ⁻⁴	4.0x10 ⁻⁴	3.2x10 ⁻³	4.6x10 ⁻⁶	3.2x10 ⁻⁴	(2)	(2)
Tetrachloroethene	1.6x10 ⁻²	5.9x10 ⁻³	5.6x10 ⁻²	8.1x10 ⁻⁵	5.7x10 ⁻³	1.6x10 ⁻⁵	3.1x10 ⁻⁵
Trichloroethene	8.2x10 ⁻⁴	3.3x10 ⁻⁴	2.9x10 ⁻³	4.2x10 ⁻⁶	2.9x10 ⁻⁴	(2)	(2)
1,1-Dichloroethene	1.7x10 ⁻³	8.1x10 ⁻⁴	6.1x10 ⁻³	8.9x10 ⁻⁶	6.3x10 ⁻⁴	(2)	(2)
1,2-Dichloroethene	1.4x10 ⁻⁴	6.3x10 ⁻⁵	4.8x10 ⁻⁴	7.0x10 ⁻⁷	4.9x10 ⁻⁵	(2)	(2)
Vinyl chloride	1.9x10 ⁻⁴	1.0x10 ⁻⁴	6.7x10 ⁻⁴	9.8x10 ⁻⁷	6.8x10 ⁻⁵	2.4x10 ⁻⁶	6.9x10 ⁻⁶
Methylene chloride	2.7x10 ⁻⁵	1.2x10 ⁻⁵	9.6x10 ⁻⁵	1.4x10 ⁻⁷	9.8x10 ⁻⁶	(2)	(2)
Naphthalene	1.6x10 ⁻³	4.6x10 ⁻⁴	5.5x10 ⁻³	8.0x10 ⁻⁶	5.6x10 ⁻⁴	2.7x10 ⁻⁵	4.0x10 ⁻⁵
2-Methylphenol	1.6x10 ⁻⁴	1.5x10 ⁻⁶	5.8x10 ⁻⁴	8.4x10 ⁻⁷	5.9x10 ⁻⁵	(2)	(2)
Carbon disulfide	1.6x10 ⁻⁴	8.1x10 ⁻⁵	5.8x10 ⁻⁴	8.4x10 ⁻⁷	5.9x10 ⁻⁵	(2)	(2)
Vinyl acetate	1.6x10 ⁻⁴	5.3x10 ⁻⁵	5.8x10 ⁻⁴	8.4x10 ⁻⁷	5.9x10 ⁻⁵	(2)	(2)
Lead	1.4x10 ⁻⁴	NA	4.8x10 ⁻⁴	7.0x10 ⁻⁷	4.9x10 ⁻⁵	(2)	(2)

(1) Calculations provided in Appendix E.

(2) Chemical not detected in vicinity of Building 1680.

NA Not applicable; inorganics are assumed to be nonvolatile.

health risk associated with exposure to that particular chemical mixture (U.S. EPA, September 24, 1986), and particular attention should be made to the target organs affected by each chemical. The Hazard Index is not a mathematical prediction of the severity of toxic effects; it is simply a numerical indicator of the possibility of the occurrence of noncarcinogenic (threshold) effects. If the ratio of the dose and the Reference Dose for any individual chemical exceeds unity, toxic effects would also be expected.

Incremental cancer risk estimates are generated for each of the exposure pathways using the estimated intakes and published Cancer Slope Factors (CSFs), as follows:

$$\text{Risk} = \text{Dose} \times \text{CSF}$$

If the above equation results in a risk greater than 0.1, the following equation is used:

$$\text{Risk} = 1 - [\exp(\text{Dose} \times \text{CSF})]$$

The risk determined using these equations is a unitless expression of an individual's likelihood of developing cancer as a result of exposure to carcinogenic chemicals. An incremental cancer risk of 1×10^{-6} indicates that the exposed receptor has a one in 1 million chance of developing cancer after the defined exposure period. Alternatively, such a risk may be interpreted as representing one additional case of cancer in an exposed population of 1 million people. The calculated cancer risks should be recognized as upper-limit estimates. Cancer Slope Factors are the upper 95 percent confidence limit of a dose-response curve generally derived from animal studies. Actual human risk, while not identifiable, is not expected to exceed the upper limit based on the CSFs, and, in fact, may be lower.

The EPA has generally defined risks in the range of 10^{-4} (1 in 10,000) to 10^{-6} (1 in 1,000,000) as being acceptable for most hazardous waste facilities addressed under CERCLA or RCRA. For CERCLA activities, residual risks on the order of 10^{-6} are the primary goal, often modified by such regulatory requirements as MCLs. Risks of greater than 10^{-6} may be acceptable if only for the short term. RCRA facilities, on the other hand, are subject to a slightly different approach according to the proposed Subpart S requirements which aim for regulatory standards for chemicals for which they are available, followed by an individual chemical risk of 10^{-6} , with a total risk not to exceed 10^{-4} .

Cancer risks are generally not calculated for small children because of the short (i.e., six years) exposure duration, unless no other receptors are being evaluated for a particular exposure. Where a

lifetime or long-term exposure is examined, the long-term risks will always be greater than for a shorter-duration exposure.

Carcinogenic and noncarcinogenic health risks are estimated using a number of different assumptions; therefore the values presented in this section contain an inherent amount of uncertainty. The extent to which health risks can be characterized is primarily dependent upon the accuracy with which the toxicity of a chemical can be estimated and the accuracy of the exposure scenario estimates. The toxicological data that form the basis for all risk assessments contain uncertainty in the following areas:

- The extrapolation of nonthreshold (carcinogenic) effects from the high doses administered to laboratory animals to the low doses received under more common human exposure scenarios.
- The extrapolation of the results of laboratory animal studies to human or environmental receptors.
- The interspecies variation if toxicological endpoints used in characterizing potential health effects resulting from exposure to a chemical.
- The variations in sensitivity among individuals of any particular species.

In addition to these sources of uncertainty, the exposure estimates presented in Section 6.4 are also based on a number of simplifying assumptions. The assumptions made include the following:

- Receptor characteristics, such as age, body weight, and exposure duration are based on published values, with some attempt at making them site-specific.
- Land use and activity patterns in the study area are primarily industrial, and direct access is restricted to base personnel both now and in the future.
- There are no antagonistic (reduction of toxic effects) or synergistic (increase of toxic effects) between chemical relationships.

The chemical analytical data base also has some limitations in such areas as sample location, sample representativeness, and the accuracy of the field laboratory results. However, every effort was made to collect samples that reflect actual site conditions.

6.5.1 Fugitive Dust Exposure (Surface Soil)

The Hazard Quotients for exposure to surface soil fugitive dust for local residents and adult employees engaged in maintenance activities are presented in Table 6-13. The table indicates the total Hazard Indices for adult residents (1.3×10^{-10}), child residents (7.1×10^{-10}), and adult employees (maintenance) (2.4×10^{-11}), are less than 1.0. Consequently, no adverse toxic effects are expected from exposure to fugitive dust under the defined scenarios.

Because the surface soil chemicals of concern are not known to be carcinogenic via the inhalation exposure route, the carcinogenic cancer risk is unquantifiable.

6.5.2 Surface Soil Exposure (Maintenance)

The estimated Hazard Quotients for direct contact with surface soil by adult employees involved in maintenance activities are summarized in Table 6-14. The Hazard Indices for incidental ingestion (3.8×10^{-7}) and dermal contact (3.3×10^{-6}) are several orders of magnitude less than 1.0, a fact that indicates that the occurrence of toxic effects under the defined scenarios is highly unlikely.

Because the chemicals of concern are not known to be carcinogenic via ingestion (which is used for dermal exposure), the carcinogenic risk via this exposure route is not quantifiable.

6.5.3 Surface/Subsurface Soil Exposure (Construction/Fire Station Personnel)

The chemical-specific Hazard Quotients for exposure to surface/subsurface soil by the adult employee engaged in a short-term construction project and local employment are presented in Table 6-15. The Hazard Indices for the incidental ingestion, dermal contact, and fugitive dust exposure scenarios are 3.4×10^{-4} , 2.7×10^{-6} , and 3.6×10^{-7} , respectively, for the construction scenario, and slightly higher for the employment scenario. Because all Hazard Indices are less than 1.0, no adverse noncarcinogenic health effects are expected under the defined scenarios.

The incremental cancer risks for exposures to surface/subsurface soil by adult fire station employees and those engaged in construction are presented in Table 6-16. The incremental cancer risks calculated for the ingestion (2.2×10^{-12}), dermal contact (1.9×10^{-11}), and fugitive dust (1.5×10^{-15}) construction exposure scenarios are several orders of magnitude less than the U.S. EPA risk range goal. The total risk to fire station personnel is 3.6×10^{-9} . major contributors to the cancer risk via

TABLE 6-13

HAZARD QUOTIENTS - FUGITIVE DUST EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Chemical	Hazard Quotient ⁽¹⁾		
	Adult Resident	Child Resident	Adult Employee (Maintenance)
Toluene	3.0×10^{-11}	1.6×10^{-10}	5.2×10^{-12}
Ethylbenzene	1.0×10^{-10}	5.6×10^{-10}	1.8×10^{-11}
Total (Hazard Index)	1.3×10^{-10}	7.1×10^{-10}	2.4×10^{-11}

(1) Calculations provided in Appendix E.

TABLE 6-14

HAZARD QUOTIENTS - SURFACE SOIL CONTACT
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Chemical	Hazard Quotient ⁽¹⁾	
	Adult Employee - Maintenance	
	Dermal Absorption	Incidental Ingestion
Toluene	6.9×10^{-7}	8.0×10^{-8}
Ethylbenzene	2.6×10^{-6}	3.0×10^{-7}
Total (Hazard Index)	3.3×10^{-6}	3.8×10^{-7}

(1) Calculations provided in Appendix E.

TABLE 6-15

HAZARD QUOTIENTS - SURFACE/SUBSURFACE SOIL EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Chemical	Hazard Quotient ⁽¹⁾				
	Adult Employee - Construction			Fire Station Personnel	
	Dermal Absorption	Incidental Ingestion	Inhalation	Dermal Absorption	Incidental Ingestion
Benzene	(2)	(2)	(2)	(2)	(2)
Toluene	2.2×10^{-7}	2.5×10^{-8}	1.8×10^{-11}	1.8×10^{-6}	2.1×10^{-7}
Ethylbenzene	7.1×10^{-7}	8.2×10^{-8}	5.4×10^{-11}	6.0×10^{-6}	6.8×10^{-7}
Tetrachloroethene	1.8×10^{-6}	2.1×10^{-7}	1.4×10^{-10}	1.5×10^{-5}	1.8×10^{-6}
Lead	(2)	3.4×10^{-4}	3.6×10^{-7}	NA	2.8×10^{-3}
Total (Hazard Index)	2.7×10^{-6}	3.4×10^{-4}	3.6×10^{-7}	2.3×10^{-5}	2.8×10^{-3}

(1) Calculations provided in Appendix E.

(2) No Reference Dose is available for this chemical and/or exposure route.

NA Not applicable. Metals are assumed to not be dermally absorbed.

TABLE 6-16

**INCREMENTAL CANCER RISKS - SURFACE/SUBSURFACE SOIL EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Chemical	Incremental Cancer Risk ⁽¹⁾				
	Adult Employee - Construction			Fire Station Personnel	
	Dermal Absorption	Incidental Ingestion	Inhalation	Dermal Absorption	Incidental Ingestion
Benzene	5.7×10^{-12}	6.6×10^{-13}	5.2×10^{-16}	9.5×10^{-10}	1.1×10^{-10}
Toluene	(2)	(2)	(2)	(2)	(2)
Ethylbenzene	(2)	(2)	(2)	(2)	(2)
Tetrachloroethene	1.3×10^{-11}	1.5×10^{-12}	1.0×10^{-15}	2.2×10^{-9}	2.6×10^{-10}
Lead	NA	(2)	(2)	NA	(2)
Total Cancer Risk	1.9×10^{-11}	2.2×10^{-12}	1.5×10^{-15}	3.2×10^{-9}	3.7×10^{-10}

(1) Calculations provided in Appendix E.

(2) No Cancer Slope Factor available for this chemical and/or exposure route.

NA Not applicable. Metals are assumed to not be dermally absorbed.

these exposure routes are benzene and tetrachloroethene, which were detected in the subsurface soil at maximum concentrations of 9.8 µg/kg and 120 µg/kg, respectively.

6.5.4 Groundwater Exposure

The Hazard Quotients for exposures to groundwater for adult residents, child residents, and adult employees is provided in Table 6-17. It should be noted that groundwater in the alluvial aquifer is not currently used as a potable water supply. The total Hazard Indices for adult residents (2.4×10^0) and child residents (8.4×10^0) exceed 1.0; consequently, the use of groundwater from the site may result in adverse noncarcinogenic health effects. The major contributors to the Hazard Indices are tetrachloroethene and naphthalene, which were detected in the groundwater at maximum concentrations of 5,100 µg/L and 110 µg/L, respectively. The total Hazard Index for the adult employee who may receive only a portion of his daily water intake from a well that is installed on site is less than 1.0 (8.6×10^{-1}). Older children playing under sprinklers installed in the alluvial aquifer could experience a total noncarcinogenic risk of less than 1.0 (7.5×10^{-2}).

The incremental cancer risks for groundwater exposures for adult residents and adult employees are provided in Table 6-18. Cancer risks are not presented for child receptors. The risks to adult residents is 1.5×10^{-3} (1 in 670 persons) for all three routes of exposure. For adult employees, the risk via ingestion only is 2.4×10^{-4} (1 in 4,700 persons). The risks for both receptor groups exceed the U.S.EPA's risk range goal of 10^{-4} to 10^{-6} . The potential risks incurred by children playing under sprinklers is 1.3×10^{-6} (1 in 770,000 persons), which is at the lower end of the risk range goal.

6.5.5 Summary

This section contains a summary of both the total Hazard Indices and the incremental cancer risks for Site S-5. The summary tables present the risks related to potential groundwater exposures separately because there are currently no water supply wells in the area.

Total Hazard Indices for all receptors exposed to soil and groundwater contaminants at Site S-5 are presented in Table 6-19. The total Hazard Indices for exposures to soil under the defined scenarios do not present an unacceptable noncarcinogenic health risk to any receptor group. The total Hazard Indices for all receptor groups are less than 1.0. However, future scenarios involving residential exposure to groundwater results in Hazard Indices that exceed 1.0. These results indicate that the use of groundwater from Site S-5 could cause adverse health effects in exposed persons.

TABLE 6-17

HAZARD QUOTIENTS - GROUNDWATER EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Chemical	Hazard Quotient ⁽¹⁾						
	Adult Resident		Child Resident	Adult Employee	Child (Recreation)		
	Ingestion and Dermal Absorption	Inhalation	Ingestion and Dermal Absorption	Ingestion	Ingestion and Dermal Absorption	Inhalation	
Acetone	9.6x10 ⁻³	(2)	3.4x10 ⁻²	3.4x10 ⁻³	5.4x10 ⁻²	(2)	
2-Butanone	1.6x10 ⁻³	4.8x10 ⁻⁵	5.8x10 ⁻³	5.9x10 ⁻⁴	4.3x10 ⁻³	6.2x10 ⁻⁴	
Benzene	(2)	(2)	(2)	(2)	(2)	(2)	
Toluene	2.1x10 ⁻³	3.1x10 ⁻⁴	7.2x10 ⁻³	7.3x10 ⁻⁴	3.7x10 ⁻³	2.9x10 ⁻³	
Ethylbenzene	7.1x10 ⁻³	(2)	2.5x10 ⁻¹	2.5x10 ⁻²	2.5x10 ⁻⁴	1.9x10 ⁻⁴	
Xylenes	4.5x10 ⁻⁴	4.3x10 ⁻³	1.6x10 ⁻³	1.6x10 ⁻⁴	2.4x10 ⁻⁵	1.2x10 ⁻³	
Chlorobenzene	2.7x10 ⁻³	4.5x10 ⁻³	9.6x10 ⁻³	9.8x10 ⁻⁴	(3)	(3)	
1,1,1-Trichloroethane	2.2x10 ⁻²	2.7x10 ⁻³	7.8x10 ⁻²	8.0x10 ⁻³	(3)	(3)	
1,1-Dichloroethane	9.1x10 ⁻³	4.0x10 ⁻³	3.2x10 ⁻²	3.2x10 ⁻³	(3)	(3)	
Tetrachloroethene	1.6x10 ⁰	(2)	5.6x10 ⁰	5.7x10 ⁻¹	1.6x10 ⁻³	(2)	
Trichloroethene	(2)	(2)	(2)	(2)	(3)	(3)	
1,1-Dichloroethene	2.0x10 ⁻¹	(2)	6.8x10 ⁻¹	7.0x10 ⁻²	(3)	(3)	
1,2-Dichloroethene	6.9x10 ⁻³	(2)	2.4x10 ⁻²	2.4x10 ⁻³	(3)	(3)	
Vinyl chloride	(2)	(2)	(2)	(2)	(2)	(2)	
Methylene chloride	4.6x10 ⁻⁴	1.4x10 ⁻⁵	1.6x10 ⁻³	1.6x10 ⁻⁴	(3)	(3)	
Naphthalene	3.9x10 ⁻¹	(2)	1.4x10 ⁰	1.4x10 ⁻¹	6.6x10 ⁻³	(2)	
2-Methylphenol	3.3x10 ⁻³	(2)	1.2x10 ⁻²	1.2x10 ⁻³	(3)	(3)	
Carbon disulfide	1.6x10 ⁻³	2.7x10 ⁻²	5.8x10 ⁻³	5.9x10 ⁻⁴	(3)	(3)	
Vinyl acetate	1.6x10 ⁻⁴	8.9x10 ⁻⁴	5.8x10 ⁻⁴	5.9x10 ⁻⁵	(3)	(3)	
Lead	9.8x10 ⁻²	NA	3.4x10 ⁻¹	3.5x10 ⁻²	(3)	(3)	
Total (Hazard Index)	2.4x10 ⁰	4.4x10 ⁻²	8.4x10 ⁰	8.6x10 ⁻¹	7.0x10 ⁻²	5.0x10 ⁻³	

(1) Calculations provided in Appendix E.

(2) No Reference Dose available for this chemical and/or exposure route.

(3) Chemical not detected in vicinity of Building 1680.

NA Not applicable, Metals are assumed to be nonvolatile.

TABLE 6-18

**INCREMENTAL CANCER RISKS - POTENTIAL GROUNDWATER EXPOSURE
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Chemical	Incremental Cancer Risk ⁽¹⁾				
	Adult Resident		Adult Employee	Child (Recreation)	
	Ingestion and Dermal Absorption	Inhalation	Ingestion	Ingestion and Dermal Absorption	Inhalation
Acetone	(2)	(2)	(2)	(2)	(2)
2-Butanone	(2)	(2)	(2)	(2)	(2)
Benzene	6.5×10^{-5}	3.1×10^{-5}	1.5×10^{-5}	1.3×10^{-7}	3.4×10^{-7}
Toluene	(2)	(2)	(2)	(2)	(2)
Ethylbenzene	(2)	(2)	(2)	(2)	(2)
Xylenes	(2)	(2)	(2)	(2)	(2)
Chlorobenzene	(2)	(2)	(2)	(3)	(3)
1,1,1-Trichloroethane	(2)	(2)	(2)	(3)	(3)
1,1-Dichloroethane	(2)	(2)	(2)	(3)	(3)
Tetrachloroethene	3.5×10^{-4}	4.5×10^{-6}	8.3×10^{-5}	9.4×10^{-8}	6.4×10^{-9}
Trichloroethene	3.9×10^{-6}	2.4×10^{-6}	9.2×10^{-7}	(3)	(3)
1,1-Dichloroethene	4.5×10^{-4}	4.2×10^{-4}	1.1×10^{-4}	(3)	(3)
1,2-Dichloroethene	(2)	(2)	(2)	(3)	(3)
Vinyl chloride	1.6×10^{-4}	1.3×10^{-5}	3.7×10^{-5}	5.3×10^{-7}	2.3×10^{-7}
Methylene chloride	8.8×10^{-8}	7.3×10^{-8}	2.1×10^{-8}	(3)	(3)
Naphthalene	(2)	(2)	(2)	(2)	(2)
2-Methylphenol	(2)	(2)	(2)	(3)	(3)
Carbon disulfide	(2)	(2)	(2)	(3)	(3)
Vinyl acetate	(2)	(2)	(2)	(3)	(3)
Lead	(2)	NA	(2)	(3)	(3)
Total Cancer Risk	1.0×10^{-3}	4.7×10^{-4}	2.4×10^{-4}	7.5×10^{-7}	5.8×10^{-7}

(1) Calculations provided in Appendix E.

(2) No Cancer Slope Factor available for this chemical and/or exposure route.

(3) Not evaluated. Chemical not detected in fuel spill area.

NA Not applicable. Metals are assumed to be nonvolatile.

TABLE 6-19

TOTAL HAZARD INDICES
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS

Route of Exposure	Hazard Index					
	Adult Resident	Child Resident	Child (Recreation)	Adult Employee (Maintenance)	Adult Employee (Construction)	Adult Employee
Inhalation of Fugitive Dust	1.3x10 ⁻¹⁰	7.1x10 ⁻¹⁰	NA	2.4x10 ⁻¹¹	3.6x10 ⁻⁷	NA
Incidental Ingestion of Soil Contaminants	NA	NA	NA	3.8x10 ⁻⁷	3.4x10 ⁻⁴	2.3x10 ⁻⁵
Dermal Absorption of Soil Contaminants	NA	NA	NA	3.3x10 ⁻⁶	2.7x10 ⁻⁶	2.8x10 ⁻³
Total Hazard Index (Soil)	1.3x10 ⁻¹⁰	7.1x10 ⁻¹⁰	NA	3.7x10 ⁻⁶	3.4x10 ⁻⁴	2.8x10 ⁻³
Potential Ingestion/Dermal Absorption of Groundwater Contaminants	2.4x10 ⁰	8.4x10 ⁰	7.0x10 ⁻²	NA	NA	8.6x10 ⁻¹
Potential Inhalation of Groundwater Contaminants	4.4x10 ⁻²	NA	5.0x10 ⁻³	NA	NA	NA
Total Hazard Index (Groundwater)	2.4x10 ⁰	8.4x10 ⁰	7.5x10 ⁻²	NA	NA	8.6x10 ⁻¹

NA Not applicable; exposure route not evaluated.

The total incremental cancer risks for all receptor groups exposed to soil and groundwater contaminants at Site S-5 are presented in Table 6-20. The incremental cancer risks for the proposed soil exposure scenarios are below the EPA's risk range goal. The calculated total risks for adult residents and employees via the groundwater exposure route are 1.5×10^{-3} and 2.4×10^{-4} , respectively. Consequently, the potable use of groundwater from this area will result in incremental cancer risks that are generally considered to be unacceptable.

6.6 ECOLOGICAL ASSESSMENT

Site S-5 is located more than one mile in a direction that is crossgradient from the nearest surface water body, which is Leon Creek. Between the site and the creek is a dry zone where the surface of Navarro Clay is elevated and wells in the alluvium produce no water.

In addition, because of the site's location near the flightline and in a fairly industrialized area of the base, no sensitive ecological receptors are present.

TABLE 6-20

**TOTAL CANCER RISK
SITE S-5
KELLY AFB
SAN ANTONIO, TEXAS**

Route of Exposure	Total Cancer Risk					
	Adult Resident	Child Resident	Child (Recreation)	Adult Employee (Maintenance)	Adult Employee (Construction)	Adult Employee
Inhalation of Fugitive Dust	(2)	NA	NA	(2)	1.5x10 ⁻¹⁵	NA
Incidental Ingestion of Soil Contaminants	NA	NA	NA	(2)	2.2x10 ⁻¹²	3.2x10 ⁻⁹
Dermal Absorption of Soil Contaminants	NA	NA	NA	(2)	1.9x10 ⁻¹¹	3.7x10 ⁻¹⁰
Total Cancer Risk	NA	NA	NA	(2)	2.1x10 ⁻¹¹	3.6x10 ⁻⁹
Potential Ingestion/Dermal Absorption of Groundwater Contaminants	1.0x10 ⁻³	NA	7.5x10 ⁻⁷	NA	NA	2.4x10 ⁻⁴
Potential Inhalation of Groundwater Contaminants	4.7x10 ⁻⁴	NA	5.8x10 ⁻⁷	NA	NA	NA
Total Cancer Risk (Groundwater)	1.5x10 ⁻³	NA	1.3x10 ⁻⁶	NA	NA	2.4x10 ⁻⁴

NA Not applicable; exposure route not evaluated.

(2) No Cancer Slope Factor available for this chemical and/or exposure route.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The following conclusions can be drawn from the data gathered during the site investigation at Site S-5, Kelly AFB:

- Site geology is characterized over most of the study area as a thin layer of fill overlaying a silty clay zone ranging in thickness from 10 to 25 feet. Below this is a silty gravel zone which overlays the Navarro Group, a regionally significant aquitard. The depth to the Navarro Group is approximately 30 feet.
- The alluvial aquifer is located in the silty gravel zone located above the Navarro Group clay. The saturated thickness ranges from 0 to 10 feet. The Navarro Group separates the alluvial aquifer from the deeper Edwards aquifer which serves as the drinking water source for the San Antonio area. The Navarro group is several hundred feet thick and therefore is the regional aquitard which effectively isolates the surficial aquifer from the Edwards aquifer. Groundwater contamination at Site S-5 is limited to the surficial aquifer.
- Groundwater flow is generally to the south. Based on three rounds of groundwater level recordings and 29 rising-head slug tests, the hydraulic gradient across the site is approximately .004 ft/ft., and the hydraulic conductivity values ranged from 12 to 198 ft/day with a geometric mean of 42 ft/day.
- Several volatile organics, dissolved lead, and petroleum hydrocarbons were detected in groundwater samples. Analytical results for Phase 2, however, were generally lower than those for Phase 1. The reason for the generally lower results is the reducing effects of dilution, migration, dispersion, and decay of the plume over time.
- There appear to be two primary sources of groundwater contamination. The Site S-5 tank farm is the major source of groundwater contamination, particularly those contaminants associated with fuels (benzene, toluene, dissolved lead, petroleum hydrocarbons). The chlorinated solvents tetrachloroethene (PCE), trichloroethene (TCE), and trans-1,2-dichloroethene (DCE) exhibit a different pattern in the groundwater, with possible sources to the south in the vicinity of Building 1600 and to the northwest, along the flightline at

the end of Billy Mitchell Road. Sources along the flightline, if any, might have originated from maintenance buildings along Billy Mitchell Road prior to World War II, when the runway did not extend beyond Billy Mitchell Road. An additional source of contamination (as seen in Figure 4-8) was a leaking underground storage tank located south of Building 1501. This tank has since been removed and the soils remediated.

- Phase 1 soil borings were located outside the tank farm. Phase 1 field laboratory data indicated soil contamination from several volatile organic chemicals. Phase 1 fixed base laboratory data, however, failed to confirm the presence of these compounds. In 1991, during Phase 2, a total of 15 subsurface soil samples were collected in the tank farm area. These data confirmed the presence of volatiles and petroleum hydrocarbons within the tank farm area. Although subsurface soils in the tank farm exhibit moderate levels of contamination particularly at or near the water table, there does not appear to be any significant soil contamination outside of the tank farm area.
- Approximately four inches of floating product was measured in one well during Phase 1. The floating product plume appeared to be localized in the immediate vicinity of the Site S-5 tank farm. During Phase 2 no discernible floating product was detected. This may have been caused by migration of the product plume past the well where product had been found during Phase 1 or by pushing of the free product into the soils by a high water table. In addition, floating product during Phase 1 may have accumulated in the well for some time.

7.2 RECOMMENDATIONS

The following recommendations for future work at Site S-5 are proposed.

- Further research into possible additional sources of groundwater contamination, particularly in the vicinity of Building 1600, is being conducted. This new site, Site S-10, has been added to Kelly's list of IRP sites based on information obtained from soil borings conducted in September 1991.
- The objective of the site characterization study and Remedial Investigation (RI) was to assess the type and extent of soil and groundwater contamination at the site. These studies were conducted in two phases at Site S-5 during 1990 and 1991. With the completion of this RI report, the objective of the RI has thus been met. A Feasibility Study (FS) is currently

being conducted to define and evaluate alternative remedial responses to the groundwater contamination.

8.0 LIST OF ACRONYMS AND ABBREVIATIONS

AFB	- Air Force Base
UST	- Underground Storage Tank
AvGas	- Aviation Gasoline
IRP	- Installation Restoration Program
NCP	- National Contingency Plan
PCE	- Tetrachloroethene
TCE	- Trichloroethene
DCE	- trans-1, 2-dichloroethene
VC	- Vinyl Chloride
DOD	- Department of Defense
RI	- Remedial Investigation
FS	- Feasibility Study
SARA	- Superfund Amendments and Reauthorization Act
HSD	- Human Systems Divisions
SA-ALC	- San Antonio Air Logistics Center
IWTP	- Industrial Waste Treatment Plant
TPH	- Total Petroleum Hydrocarbons
VOH	- Volatile Organic Halocarbons
FOL	- Field Operations Leader
TCLP	- Toxicity Characteristic Leaching Procedure
TOX	- Total Organic Halogens
BTEX	- Benzene, Toluene, Ethylbenzene, and Total Xylenes
QC	- Quality Control
MSL	- Mean Sea Level
T.O.C.	- Top of Casing
QA	- Quality Assurance
RCRA	- Resource Conservation and Recovery Act
TDH	- Texas Department of Health
ZHE	- Zero Headspace Extraction
MCL	- Maximum Contaminant Level
ND	- Not Detected
NA	- Not Analyzed
PAHs	- Polynuclear Aromatic Hydrocarbons

PCBs - Polychlorinated Biphenyls
BCFs - Bioconcentration Factors
AWQC - Ambient Water Quality Criteria
RfDs - Reference Doses
CSFs - Cancer Slope Factors
UCL - Upper 95 Percent Confidence Limit
NOEL - No-Observed-(Adverse)-Effect-Level
NOAEL - No-Observed-(Adverse)-Effect-Level
LOAEL - Lowest-Observed-(Adverse)-Effect-Level
MCLGs - Maximum Contaminant Level Goals
ARARs - Applicable or Relevant and Appropriate Requirements
CERCLA - Comprehensive Environment Response, Compensation and Liability Act